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The American Association for the Advancement of Science:
Earth Structure and Earth Origin: PROFESSOR KIRTLEY F. MATHER 65
Obituary:
Edwin Herbert Hall: PROFESSOR P. W. BRIDGMAN 70
Scientific Events:
The First High-powered Radio Station without Static; Grants of the National Foundation for Infantile Paralysis; The Annual Meeting of the Southwestern Division; The American Institute of the City of New York and the American Association for the Advancement of Science; Awards of the American Society of Civil Engineers; Scientific Research under the Federal Government 72
Scientific Notes and News 75
Discussion:
Undertow: DR. F. P. SHEPARD and E. C. LAFOND. *Survival of the Tropical Rat Flea in United States:* DR. ROBERT L. ROUDABUSH. *Rediscovery of the Rhizocephalan Peltogaster Paguri on the North American Coast:* PROFESSOR EDWARD G. REINHARD. *Nomenclature of Gonad-stimulating Hormones of Placental Origin:* DR. E. B. ASTWOOD and DR. R. O. GREEP 78
Scientific Books:
Crystal Physics: DR. HANS VONR. JAFFE. *Insects of Subtropical Fruits:* DR. RALPH H. SMITH 81
Special Articles:
An Estimate of the Maximum Value for the Molecular Weight of the Tobacco Mosaic Virus Protein: PROFESSOR VERNON L. FRAMPTON and DR. A. M. SAUM. *Relation between the Increase in Opacity of Yeast Suspensions during Glucose Metabolism and Stimulation:* DR. THEODORE J. B. STIER, M. ISABEL NEWTON and HERBERT SPRINCE. *The Use of Purified Thrombin as an Hemostatic Agent:* DR. W. H. SEEGERS and OTHERS. *Isolation of Crystalline Heterotrypsin from Beef Pancreas:* DR. KLAUS HOFMANN and DR. MAX BERGMANN 84
Scientific Apparatus and Laboratory Methods:
Method for "Fixing Ice Crystal Patterns" in Frozen Products: DR. J. G. WOODROOF. *A New Apparatus and Method for Training the Rat in Auditory Discrimination Problems:* W. A. HUNTER and PROFESSOR L. A. PENNINGTON 87
Science News 6

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EARTH STRUCTURE AND EARTH ORIGIN[1]

By Professor KIRTLEY F. MATHER

HARVARD UNIVERSITY

IN his book "The Solar System and Its Origin,"[2] Henry Norris Russell presents a critique of the several theories of earth origin, which may fairly be taken as representative of the attitude of most astronomers toward this problem, responsibility for the solution of which they share with geologists. Full consideration is given to the planetesimal hypothesis of Chamberlin and Moulton and to the modifications of that hypothesis which have been proposed by Jeffreys and Jeans. The obstacles which forbid whole-hearted acceptance of any one of these hypotheses are forcefully presented. The conclusion is frankly stated "that no one can yet say how our system originated in detail."

It is nevertheless apparent that the most hopeful line of research leads toward some hypothesis of origin during an encounter between the sun and another heavenly body. In other words, the fundamental principle of the planetesimal hypothesis is accepted. Future investigators are most likely to work toward the discovery of the particular modification of that hypothesis which will best fit the facts now known or to be ascertained.

Commenting specifically upon the planetesimal and tidal theories, Professor Russell states: "It is here that the two theories part company—the planetesimal supposing that the existing planets were formed mainly by the slow agglomeration of small cold bodies, and the tidal that they were all once liquid and have picked up much less matter in later times. This difference, while very important to the geologist, is really rather small from the standpoint of the astronomer."[3]

[1] Address of the vice-president and chairman of Section E, American Association for the Advancement of Science, Richmond meeting, December 28, 1938.

[2] New York, 1935.

[3] *Loc. cit.*, p. 102.

Geologists, as such, are deeply concerned with the problem of earth origin primarily because they want to know whether the earth was essentially molten at some time in the past, after it had attained the state of a separate planetary body possessing approximately its present mass, or whether it was an essentially solid and relatively small planetary body to which has been added a considerable fraction of its present mass by some process of accretion. Upon the answer to that question depend some of the most fundamental ideas concerning diastrophism and vulcanism. No satisfactory theory concerning the processes of mountain-making, the origin of igneous rocks, the mechanism of volcanic eruptions or the dynamics of isostasy can be formulated without a commitment concerning that phase of the juvenile history of the earth.

Apparently, the geologist can not expect the astronomer to tell him the answer which he thus needs to learn. He must secure it for himself by investigating the structure of the earth's interior and by reasoning backward from observed geological phenomena to the antecedent conditions which alone can explain all the intricate details of the present structure of the earth's exterior.

That the earth has grown by the addition of extra-terrestrial matter is of course a conclusion based on direct observation. Reliable estimates of the number and average weight of meteorites which have reached the earth during the last few years indicate that the daily accretion of meteoric dust is of the order of magnitude of 50,000 tons.[4] This would mean that the earth's mass is increasing at a rate of approximately 20,000,000 tons per year. At that rate the earth would have acquired 2×10^{16} tons of previously extra-terrestrial matter in a billion years and twice that amount, or 4×10^{16} tons, in the two billion years which seem to have elapsed since its birth. That stupendous mass is, however, only one one-hundred-and-twenty-five thousandths of the present mass of the earth, roughly 5×10^{21} tons. If one half or two thirds of the earth's body has been built up through planetesimal accretion, the rate of infall must have formerly been a hundred thousand times as great as it is to-day. This is of course explicitly accepted in the planetesimal hypothesis, but it throws the whole question back into the realm of speculative deduction. On the other hand, we may note that 4×10^{16} tons of matter with an average density of 3.0 would form a layer only a little more than 100 feet thick around the earth.

That fact probably has no real significance, but it at least serves to direct our attention at this point to the problem of the physical condition and chemical composition of the earth's interior. Geophysical research has yielded much important data during the last two decades, and ideas concerning the fundamental structure of the earth are now taking definite and trustworthy form.

The records of earthquakes indicate unmistakably that the earth has a stratiform structure. Its body is composed of several successive shells which differ from each other in elasticity, as indicated by the travel-times of the seismic vibrations. The central core of the earth, approximately 2,200 miles in radius, is notably different from the surrounding shells in its physical properties. The several shells and the earth core are separated from each other by surfaces or transition zones appropriately known to the seismologist as discontinuities. Most of the discontinuities are marked by a fairly abrupt change in the velocity of propagation of the seismic vibrations and hence are known as discontinuities of the first order. Some are marked by a variation in the rate of change in velocity with increased depth and hence are known as discontinuities of the second order.

The statements in the preceding paragraph would probably be accepted as valid by all competent investigators in this field and may therefore be used as basic data upon which any useful concept of earth structure must be constructed. They present in general terms the specifications which must be met by any satisfactory theory of earth origin. It is indeed the demonstration of the stratiform structure of the earth which more than anything else has caused many geologists to become skeptical of the adequacy of the planetesimal theory of earth origin and to look with favor upon a theory in which the juvenile earth is conceived to have been essentially a liquid globe at the time it possessed approximately its present mass.

There yet remain a multitude of unanswered questions concerning the earth shells and the earth core. Divergent interpretations of the same data have been made by several competent investigators. Essential data concerning the response to stress of earth materials under conditions of great pressure and high temperature are still lacking, and at present the deficiency can be met only by untrustworthy extrapolation or debatable assumption. The available information concerning travel-times, refractions and reflections of seismic vibrations is inadequate for the incontrovertible appraisal of the several working hypotheses and must be amplified by the study of records secured in the future at existing seismograph stations or at stations which should be established to complete the necessary network of such stations the world around. It should nevertheless prove helpful to review the present state of knowledge and inference, with special consideration of its bearing upon the problem of earth origin.

It would appear that no doubt can now remain con-

[4] *Cf.* H. H. Nininger, "Our Stone-Pelted Planet," p. 91. Boston, 1933.

cerning the crystalline nature of earth materials down to a depth of at least 60 kilometers. Above that depth, within continental segments, there seem to be at least three shells which differ from each other in their responses to stress. The outer shell beneath the surficial and discontinuous veneer of sedimentary or metamorphic rock is granitic in composition, the next is an intermediate zone which may be composed largely of diabasic or gabbroic rocks, and the third consists of materials which behave as either pyroxenite or dunite would probably behave at such depths.[5] The last-mentioned shell constitutes the "crystalline sima," as that term is used by Daly,[6] who, however, considers its composition to be more like that of gabbro than of peridotite. It is believed to be continuous beneath the oceans the world around. Readily recognized discontinuities of the first order separate these shells from each other. Thicknesses of the shells and hence depths to the discontinuities vary considerably from place to place. Most of the figures cited by those who have generalized upon the matter are average figures rather than specific ones.

The determination of the depth of a discontinuity depends at present upon the selection of certain assumptions from several which appear almost equally reasonable concerning the propagation of vibrations in the earth's interior as well as the choice of the particular measurement of wave velocities which shall be applied. Consequently, different investigators working with the same data have reached different conclusions, and diverse data secured at various localities have yielded notably different results. This, however, does not in the least invalidate the general principle that discontinuities are present and that the earth is composed of successive shells with unlike properties.

As expected, the limits within which our present knowledge confines the selection of data are much narrower for the shallow than for the greater depths. Laboratory conditions can be established which closely imitate the conditions of pressure and temperature existing at depths approximating 25 kilometers and of pressure at depths of at least twice that figure. Field studies involving the use of artificially generated vibrations include the accurate determination of traveltimes for impulses originated by dynamite blasts transmitted for distances as great as 175 miles. Thus the depth of the discontinuity at the inner surface of the granitic shell beneath southern New England is rather definitely fixed as 14.5 kilometers.[7] Data from other localities, as interpreted by various geophysicists, indicate depths between 10 and 25 kilometers.

[5] Francis Birch and Dennison Bancroft, *Jour. Geol.*, 46: 59–87, 113–141, 1938.

[6] R. A. Daly, "Architecture of the Earth," pp. 51–59. New York, 1938.

[7] L. D. Leet, *Bull. Seismol. Soc. America*, 28: 45–48, 1938.

The intermediate zone is computed variously to have a thickness of 15 to 40 kilometers. The depth to the discontinuity at its inner surface is between 25 and 60 kilometers; Daly uses 40 kilometers as an average determination. Sharpe[8] computes its average depth beneath 17 widely scattered stations as 32 kilometers. Differences in the determinations are almost certainly due to actual variations in the thickness of the two outer earth-shells from place to place and not entirely to differences in interpretation of data.

The depth to which the crystalline sima extends is still a question for speculative consideration. The next clear-cut discontinuity of the first order, below the bottom of the intermediate zone, which has been generally recognized, is at a depth of approximately 475 kilometers. There are, however, some significant data concerning shadow-zones and wave amplitudes which have been interpreted by Gutenberg[9] as suggesting the presence of material having a slightly lower velocity beneath the high-speed crystalline sima at a depth of 60 or 70 kilometers. Daly computes[10] that the temperature below 60 kilometers is such that the sima must be in a vitreous rather than a crystalline state. This would of course explain the apparent retardation of the wave of dilatation at a depth of 60 or 70 kilometers and would thus be in keeping with the seismological specifications.

Temperatures and pressures at depths between 60 and 400 to 500 kilometers are such as to put rock materials very close to the boundary between the vitreous and crystalline states. It requires only a rather steep, but still perfectly plausible, temperature gradient to yield the computations upon which Daly bases his concept of a vitreous substratum. A slightly lower temperature gradient, offset by the increase in pressure, would permit the crystalline state to persist to greater depths; the precise temperature gradient, density distribution and chemical composition selected would determine the depth at which a vitreous rather than crystalline state would be found. Under reasonable assumptions it seems almost certain that beyond a depth of a few hundred kilometers, because of the great pressures there prevailing, the earth materials, if lithic rather than dominantly metallic, must be crystalline. As pointed out by Daly,[11] "the vitreous basaltic shell (must) be relatively thin, perhaps nowhere more than a few scores of kilometers in thickness." Possibly the 475 ± kilometer discontinuity marks the change from vitreous to crystalline materials rather than merely the increase in the intrinsic density re-

[8] J. A. Sharpe, *Bull. Seismol. Soc. America*, 25: 199–222, 1935.

[9] B. Gutenberg, Grundlagen der Erdbebenkunde, Berlin, 1927. See also Daly, *loc. cit.*, pp. 67–69.

[10] *Loc. cit.*, p. 62.

[11] *Loc. cit.*, p. 69.

quired to meet the specifications necessary to give the earth its known moment of inertia.

The unanswered question concerning the physical state of the material in this relatively thin substratum may never be resolved by seismic research. Birch and Bancroft[12] report that "the velocities in crystalline and vitreous gabbroic materials tend to become equal as the temperature increases." If this tendency actually establishes equivalent velocities, the question becomes meaningless so far as seismology is concerned.

There is, however, another question of great importance to both geologist and cosmogonist, although significant for different reasons when considered from one or other of these two view-points. That is the question of the intrinsic strength of the materials in this quasi-vitreous substratum. This is the zone, or a part of the zone, to which Barrell long ago applied the apt term, asthenosphere. Much evidence has accumulated to strengthen the geologist's belief in the correctness of the essentials of Barrell's concept. Only on the assumption that the substratum is unable to withstand any appreciable accumulation of long-continuing stress can one explain many of the observations concerning isostatic adjustment, as for example those pertaining to the phenomena of loading and unloading the earth's crust during a glacial episode. Daly[13] has recently emphasized anew the extreme weakness of the asthenosphere. Using data from Hirvonen and Witting, he finds that the maximum strength at a depth of 100 kilometers is less than 2.5 kilograms per square centimeter. This computation should be compared with Barrell's estimate of 200 to 300 kilograms per square centimeter and with Jeffreys' calculation of 100 kilograms per square centimeter.

Probing still deeper into the earth's inaccessible interior, we find that seismologists have recognized several discontinuities between 475 ± kilometers and 2,900 kilometers. The position of these discontinuities is, however, subject to almost constant revision as new data are obtained or old data are reinterpreted. At least one of them, located somewhere near 1,000 kilometers beneath the surface, is a discontinuity of the second order and it may prove at last that all of them are actually in this category, marking a change in the rate of increase of velocities rather than an abrupt change in the velocities themselves. Certainly there can be at present no confidence in the precision of any of the announced locations of supposed discontinuities of the first order in this subterranean region. Such discontinuities may exist, but if they do their position can not now be determined with anything like the accuracy which pertains to those at shallow depths beneath the continents.

On the other hand, it appears quite certain from a consideration of the requirements imposed by the earth's known moment of rotational inertia that the changes in density with depth in this zone are due to differences in the chemical composition of the materials, not merely to increased compaction of like materials under increased load. These requirements are best satisfied if we postulate the presence of a shell of rock material having the chemical composition of dunite or peridotite beneath the quasi-vitreous substratum. Toward the inner surface of this shell there must be increasing quantities of material "chemically like the iron-bearing stony meteorites"[14] and below a depth which may be in the neighborhood of 1,000 kilometers the earth shell must be essentially of that type of substance.

At approximately 2,900 kilometers there is a well-recognized discontinuity of the first order. Below that depth, earthquake waves encounter material giving much lower velocities than those which characterize their transmission in the immediately superjacent zone. This explains the well-known "shadow zone" between 105 and 142 degrees from the epicenter of world-shaking earthquakes.[15] This discontinuity marks the effective surface of the earth's core, frequently designated the "iron core," because a composition of iron and nickel in approximately the same ratio as those metals display in the iron meteorites would probably give the required velocities for longitudinal vibrations (waves of dilatation) under reasonable assumptions for temperature and pressure.

Thus far, no unchallengeable identification of a seismogram phase as due to a wave which passed through the earth's core as a shear wave (transverse vibration) has been announced. Such waves can not be transmitted through liquids, but it is probably misleading to say that it is therefore known that the iron core is a liquid core. To call it a quasi-liquid core would give a more accurate impression. There is at present no knowledge concerning the behavior of any metallic solid under the conditions of temperature and pressure which must maintain at great depth within the earth. The molecules of iron and nickel may be associated in the earth's core in ways that transcend all human experience with solids, liquids or vapors.

Turning then from conjectures that could hardly be profitable, we note the bearing which the concept of a stratiform earth may have upon the theories of earth origin. Any earth model capable of satisfying the requirements of modern knowledge concerning the

[12] Francis Birch and Dennison Bancroft, *Jour. Geol.*, 46: 141, 1938.

[13] R. A. Daly, *Trans. Am. Geophys. Union*, 19th Ann. Meeting, pp. 35–39, 1938.

[14] *Cf.* Daly, *loc. cit.*, p. 69.

[15] *Cf.* L. D. Leet, "Practical Seismology and Seismic Prospecting," pp. 161–168. New York, 1938.

physical properties of the earth's interior must inevitably present a challenge to the planetesimal theory. To provide a stratiform earth by specific gravity settling is a relatively simple proposition for a molten-earth theory such as the tidal theory of Jeffreys and Jeans, but it is not immediately apparent that an earth built in large part by planetesimal accretion would attain that structural configuration. Accepting this challenge, T. C. Chamberlin in his later presentations of the planetesimal theory[16] rejected the enticing detour which would involve the liquefaction of the planet after its growth by accretion had been practically completed. "There does not seem to be any cogent reason for assuming that molten planets would arise from this mode of aggregation, except in those cases in which the knots were very large."[17] He proposed instead that the stratiform structure arose in part from the selective nature of the processes of accretion and in part from selective vulcanism, both of which would tend to segregate the denser and more metallic or less silicic substances toward the center, and the less dense and more silicic substances toward the periphery of the juvenile earth. Chiefly because of skepticism concerning the quantitative effectiveness of these selective processes, Chamberlin's attempt to explain the stratiform structure within the framework of the planetesimal theory has never met with wide-spread approval.

In view, however, of our present knowledge of the behavior of crystalline and vitreous solids under conditions of great pressure and high temperature, it would appear that this stumbling-block has been removed. The intrinsic strength with which such solids resist deforming stress is astonishingly slight. Convection must occur in an asthenosphere as weak as the quasi-vitreous substratum appears to be, if there are appropriately located differences in density due either to variations in chemical composition or to changes in temperature. Ideomolecular reorganization of crystals is stimulated in crystalline solids under the conditions which prevail throughout the earth's interior beneath a thin surficial zone. It is indeed quite impossible to prevent the earth, regardless of initial heterogeneity of materials, from developing a stratiform arrangement of those materials according to density, as slow adjustment takes place within its body during its long history.

Thus an earth originally heterogeneous and always essentially crystalline would eventually be organized into its present structural form with a central core of intrinsically dense materials surrounded by concentric shells of progressively less dense substances. At all times it would react as an elastic solid to the sudden impacts or abrupt release of energy which initiate earthquake vibrations, but at all times it would be subject to "solid flow," which would tend inevitably toward specific gravity assortment. If this is true, the existing structure of the earth's interior could be explained with equal effectiveness regardless of its origin, whether by planetesimal growth or by condensation from a gaseous "filament." This would mean that the geologist would be unable to use the earth's fundamental structure as a criterion for appraising the relative merits of the planetesimal and the tidal hypotheses.

There is, however, another consideration which may put him in a better position to pass judgment in this particular court of appeal. Somewhere in his cosmogony he must find a place for the forces which have produced the folded structures in the earth's outermost shell and the fundamental differences between the continental and oceanic segments. The former involve the horizontal compression of certain portions of the lithosphere; the latter involve the segregation of granitic materials in the continental protuberances. Here there is an essential difference between the two theories of earth origin.

Several alternative theories of mountain-making diastrophism are worthy of attention. These include horizontal shifting of earth-blocks as a result of convection currents in the substratum, or of de-leveling, or of forces resulting from the earth's rotation as a planet with which a large satellite is associated. These avenues of investigation should be pursued, but at the moment none of them appear particularly promising. Volume changes due to local alterations in temperature seem wholly inadequate to explain the known crustal shortening. The oldest theory of all, circumferential shortening of a radially shrinking earth, appears to be still the most favorable lead. The effects of earth condensation would produce structures such as we find in every great chain of mountains; the efficiency of the process is unquestioned. The problem is to explain earth-shrinkage itself.

All investigators agree that the rate at which the earth loses its body heat is altogether too small to account for more than a trivial fraction of the shrinkage necessary to explain the amount of circumferential shortening revealed by post-Cretaceous mountain-making compression. We may say quite dogmatically that the cooling of the earth is not an adequate cause of the known horizontal compression of the lithosphere. There remains the possibility that physical and chemical reorganization of the materials composing the earth's interior has been such as to increase sufficiently their average density and thus produce the required decrease in volume for the earth as a whole. Chamberlin long ago appealed to this process in seeking an explanation for the diastrophism which pro-

[16] T. C. Chamberlin, "The Origin of the Earth," Chicago, 1916, and "The Two Solar Families," Chicago, 1928.

[17] T. C. Chamberlin, *loc. cit.*, 1916, p. 147.

duces folded and overthrust mountains. The argument is still valid. It applies, however, only to an earth constructed according to the planetesimal program; it is utterly ineffective in an earth which has solidified from a molten state. If at last we find no escape from the idea of a shrinking earth, we must render our verdict in favor of the planetesimal theory rather than the tidal.

The second basis for testing the theories of earth origin is found in the attempt to explain the segmentation of the lithosphere into continents and ocean basins. Here the problem is to account for the segregation of less dense, granitic materials beneath the protuberances and the denser, gabbroic material beneath the basins. Chamberlin's explanation was in terms of selective in-gathering of planetesimal debris under the influence of atmospheric circulation, combined with selective placement of the products of weathering by the agents of transportation and deposition. Under the tidal theory, the segmentation of the granitic shell, originally continuous the world around, must be accomplished during the rupture accompanying the birth of the moon. Both ideas must be critically reviewed in the light of any new knowledge which may be secured in the coming years. Neither can be whole-heartedly accepted or bluntly rejected at the present moment. The line of departure between the two is so clearly defined and leads to such far-reaching consequences that there is good reason to expect a definite verdict in the near future. The bearing of that verdict upon the theories of earth origin is obvious.

In summary, it would appear that the concept of earth structure based on recent geophysical and seismological research is not nearly so unfavorable to acceptance of the planetesimal theory of earth origin as many geologists have supposed it to be. On the contrary, in at least one particular—that which deals with the origin of folded mountains—modern investigations pertaining to the fundamental structures of the earth have brought renewed confidence in the basic principles of that theory.

OBITUARY

EDWIN HERBERT HALL

PROFESSOR EDWIN HERBERT HALL, universally known to physicists as the discoverer of the Hall effect, died on November 20, 1938, at the age of 83 years. He was born in Gorham, Maine, on November 7, 1855, fitted for college in Gorham Seminary, entered Bowdoin at 15, and graduated with the A.B. degree at the head of his class at 19. During 1875–76 he taught as principal at Gould's Academy in Bethel, Maine, and during 1876–77 was principal of the Brunswick High School. In 1877 he entered the Johns Hopkins University as a graduate student of physics, and from 1878 to 1880 was fellow in physics, working under Rowland and receiving the Ph.D. degree in 1880. He continued on as assistant in physics during 1880–81, when he was appointed to a Tyndall scholarship for study and travel abroad. During the summer he made measurements on the "Hall" effect in Helmholtz's laboratory in Berlin, and read a paper reporting these measurements at the York meeting of the British Association in the summer of the same year. He returned to this country in the fall of the same year to an instructorship in physics at Harvard, a position which he held until 1888. From 1888 to 1895 he was assistant professor at the same institution, professor from 1895 to 1914, Rumford professor from 1914 to 1921, and professor emeritus from 1921 till his death. He was a member of the A.A.A.S. (vice-president of the section of physics in 1904), of the American Physical Society, the American Academy of Arts and Sciences, the National Academy of Sciences, corresponding member of the British Association for the Advancement of Science and foreign member of the Société Hollandaise des Sciences. He received the LL.D. degree from Bowdoin in 1905, was a member of the Solvay Congress at Brussels in 1924 and of the Volta Congress in Como in 1927, and in 1937 received the award and medal of the American Association of Physics Teachers for notable contributions to the teaching of physics, and was made the first honorary member of the association.

Professor Hall's great contribution to the teaching of elementary physics was a pioneering contribution, made at a time when physical laboratories were almost unheard of in this country. In 1886 he published, with the encouragement of President Eliot, the well-known "Harvard Descriptive List of Elementary Physical Experiments." These had the unique merit of demanding apparatus simple enough so that it could in many cases be constructed by the teachers themselves without undue strain on their meagre budgets. This "list" was followed by several elementary text-books, the best known perhaps being "A Textbook of Physics" by Hall and Bergen in 1891. It would not be unfair to describe Professor Hall's work as entirely remolding the scheme of secondary school physics, and as such exerting a most important influence, but since this matter is freshly in mind through the articles in the *American Physics Teacher* for February, 1938, at the time of the award, it is not necessary to elaborate further here.

Of course Professor Hall will always be best known for the Hall effect, discovered while working for his

Ph.D. degree with Rowland in 1879. This effect is usually described as a difference of potential transverse to the lines of current flow, which appears when a magnetic field is applied perpendicular to the current. It had been vaguely predicted by Kelvin in 1851, expected and vainly searched for by a number of experimenters, including Rowland himself, independently expected by Professor Hall and found only after a couple of unsuccessful attempts. The pertinacity which kept him at the search for the suspected effect remained one of his most striking characteristics. The announcement of the discovery was received with the greatest interest. Of it Kelvin said in commenting on Hall's paper at the York meeting of the British Association in 1881: "The subject of this communication is by far the greatest discovery that has been made in respect to the electrical properties of metals since the times of Faraday—a discovery comparable with the greatest made by Faraday." A large number of other investigators rushed into the field thus opened. The three other analogous transverse effects bearing the names of Ettingshousen, Nernst and Righi-Leduc were speedily discovered, and a very extensive literature rapidly grew up.

Professor Hall himself continued to contribute papers on the new effect for eight years, but then turned for a considerable interval to other matters, mostly related to questions of thermodynamics, which was his principal field of graduate instruction. He was thus led to take up the thermo-dynamic analysis of thermo-electric phenomena, to which he contributed new points of view. In his attempt to understand the mechanism of these phenomena he was confronted with the whole problem of the theory of electrical phenomena in metals. He had the vision to realize that the significance of the Hall phenomenon and the other transverse effects had not been adequately appreciated, and his scientific life from 1910 on was dedicated with rare singleness of purpose to creating a theory of electrical phenomena in metals which should include thermo-electric and the transverse phenomena as well as those more usually considered. Part of his program demanded better numerical values for the various transverse coefficients. The exact measurement of these coefficients is admittedly one of the most difficult tasks which an experimental physicist can set himself, but with marvelous spirit Professor Hall undertook the problem after the construction of the new Research Laboratory for Physics at Harvard in 1931, and had succeeded in measuring the four coefficients for a number of metals as a function of temperature with an accuracy which satisfied his exacting requirements. He was actively engaged on this work up to within a few weeks of his death.

His theoretical work has probably never received the attention that it deserved because it was written in an idiom of his own, not familiar to most theoretical physicists. For a number of years before his death he had been attracted by the idea of collecting his theoretical results into a book, and actually was on the verge of publication a couple of times, but finally last summer (1938) he issued a book of 170 pages, considerably smaller than he had at one time contemplated, entitled, "A Dual Theory of Conduction in Metals," published by the Murray Printing Company, Cambridge. This book, I think, will be found to be much more readable than many of the original papers, and to be well worthy of intensive study. It should not be difficult to put into the language of present quantum theory many of Professor Hall's points of view. It was a particular gratification to him toward the end of his life that quantum theory found itself naturally driven to a point of view on the importance of which he had always insisted, namely, that conduction phenomena can not be understood without considering the rôle of the positive ions in the metal as well as the free electrons.

Those who knew him personally will feel a loss greater than can be accounted for by any scientific eminence. It will be agreed, I believe, that his outstanding personal characteristic was his utter honesty and integrity, coupled with an independence and strength of character which enabled him to trust his own judgment and steer his own course once he had made his carefully reasoned decision. Combined with this was a very unusual reluctance to force his own views on others; he truly treated the opinions of others as equally worthy of respect with his own. He was unobtrusively but consistently and persistently religious, with a strong sense of civic duty. He served in executive positions of importance in a number of community enterprises, and his volunteer services at the time of the Boston police strike will be long remembered. His conversation was often enlivened by a refreshing wit, and his writings by a felicity that made them a pleasure to read. His satisfaction with writing as a means of expression probably went back to his college years, for he described himself as the most prolific editor of the college paper, and refers to writing as the only talent he may have had in college. On occasion he was capable of effective verse. Those who knew him more intimately knew that he had passed through dark times of discouragement or even despair, over which he triumphed by sheer force of character. Sometimes they were permitted glimpses of a depth and quality of sentiment rare and moving.

His friends will not soon forget the erect vigor of his old age, or cease to be thankful that his last illness was not protracted.

P. W. BRIDGMAN

HARVARD UNIVERSITY

SCIENTIFIC EVENTS

THE FIRST HIGH-POWERED RADIO STATION WITHOUT STATIC

THE first high-powered radio station without static, employing an improved system of transmission and reception which, if widely adopted, will take the place of radios now in use, will be put into operation next spring, according to an announcement made by Major Edwin H. Armstrong, professor of electrical engineering in Columbia University, who designed and built the broadcasting equipment.

The new system will greatly relieve the danger of the air waves being monopolized, which has given so much concern to the Congress, by making available a service on the ultra-high frequency channels that are comparatively unused at present.

Arrangements have been made with station WQXR for the new station to receive and transmit the programs now broadcast from New York's "High Fidelity" station. John V. Hogan, radio engineer and owner of WQXR, has filed a petition with the Federal Communications Commission for permission to build a frequency modulated station in New York City. The studios and programs of WQXR will be used by W2XMN until such a time as Mr. Hogan's own station is erected.

Construction of frequency modulated receiving sets of the new type, which were at first labeled an "impractical dream" by radio corporations, has already been started on a commercial basis by the General Electric Company. The new sets, when produced on a quantity basis, will cost no more than the ordinary good set of to-day and will be able to receive both the old and the new kinds of broadcasting much the same as sets now receive both the short and long-wave programs. Arrangements are being made for the manufacture and sale of transmitters by the Radio Engineering Laboratories of Long Island City. Patents on the system have been granted to Major Armstrong in the important countries of the world.

The invention was publicly demonstrated before the Institute of Radio Engineers in 1935. At that time a sound reel recording was played comparing the reception during a thunder-storm of the old and new types of broadcasting. The recording was made from broadcasts received at a distance of 85 miles from the 2-kilowatt station in the Empire State Building, using the new method, and from WEAF, a 50-kilowatt station. While WEAF came through strongly, its program was made unintelligible by crashes of static. In contrast, the frequency modulated signals from the Empire State Building provided an uninterrupted, clear program, free from static, despite the fact that its power was only 4 per cent. that of the larger station.

Major Armstrong states that great credit for the development work necessary to perfect the high quality of the transmission must go to John Bose and James Day, two of his assistants. Apparatus for the station was designed in the Hartley research laboratories at Columbia University, where the most delicate parts were made. The remainder of the equipment was constructed at the Radio Engineers Laboratory in Long Island City and the RCA Manufacturing Company of Camden. Major Armstrong paid the highest tribute to the engineering skill of John Evans, of the RCA Company, who designed the high-power equipment and to Perry H. Osborn, who assisted in the construction.

The new station, built at a cost of several hundred thousand dollars, is owned by Major Armstrong. He first started to work on the problem of eliminating static from radio broadcasts in 1914 in collaboration with Professor Michael I. Pupin, after whom the Pupin laboratories at Columbia are named. Both men gave up the problem in 1922, convinced that there was no solution. A year or two later Major Armstrong started to look for a solution from a new angle that eventually led to the present discovery.

GRANTS OF THE NATIONAL FOUNDATION FOR INFANTILE PARALYSIS

THE National Foundation for Infantile Paralysis has announced grants of $140,990 to universities and hospitals. They are as follows:

For Scientific Research

Department of Internal Medicine, Yale University Medical School, $6,500.
Long Island College of Medicine, Brooklyn, $15,000.
Department of Bacteriology, University of California Medical School, Los Angeles, $5,000.
Department of Bacteriology, University of Southern California Medical School, $10,000.
Department of Bacteriology, Stanford University, California, $12,000.
University of Michigan, Ann Arbor, $2,000.
University of Wisconsin, Medical School, Madison, $3,300.
Department of Bacteriology, Ohio State University, Columbus, $3,060.
Western Reserve University, Cleveland, $4,800.
Washington University, School of Medicine, St. Louis, $6,800.
Grasslands Hospital, Valhalla, N. Y., $7,500.

For Prevention and Treatment of After Effects

Orthopedic Hospital-School, Los Angeles, $7,800.
Children's Hospital-School, Baltimore, $7,500.
St. John's Hospital, Springfield, Ill., $2,500.
Michael Reese Hospital; Samuel Deutsch Serum Center, Chicago, $4,600.

James Whitcomb Riley Hospital, Indianapolis, $6,000.
Children's Hospital, Marlin, Texas, $2,500.
Society of New York Hospital, New York, $4,580.
University Hospital of Iowa, Iowa City, $8,500.
Hospital for Joint Diseases, New York City, Dr. Leo Mayer, surgeon in chief, $4,250; Dr. Samuel Kleinberg, $5,800; Dr. Samuel Johns and Dr. Isador Zadek, $5,500; Dr. Jerome Weiss, director of division of poliomyelitis research, $5,500.
Scottish Rite Hospital, Dallas, Texas, $10,000.

The grants for research were made upon the recommendation of an advisory committee headed by Dr. Thomas M. Rivers, director of the hospital of the Rockefeller Institute for Medical Research. Dr. Philip Lewin, associate professor of orthopedic surgery at the Medical School of Northwestern University, was chairman of the committee which directed distribution of the grants for treatment.

Grantland Rice is chairman of a committee for raising funds prior to the birthday balls of President Roosevelt on January 30. This year the funds will be divided in half, one part to remain in the localities where the money is raised and the other half to be sent to the National Foundation for Infantile Paralysis for support of research and new treatment.

THE ANNUAL MEETING OF THE SOUTHWESTERN DIVISION

THE nineteenth annual meeting of the Southwestern Division of the American Association for the Advancement of Science will be held from May 2 through May 5 at Alpine, Texas. Host institutions will be the Sul Ross State Teachers College and the new McDonald Observatory, the latter being located on top of Mt. Locke, 42 miles from Alpine. Presentation of papers in the various sections will be held at Alpine during the first three days, with the fourth to be spent at the observatory.

Alpine is located in the Big Bend region of Texas, almost due east of El Paso at a distance of 225 miles. It is on one of the main east-west highways (U. S. 90), all paved. The McDonald Observatory is a joint enterprise of the University of Texas and the University of Chicago, with Dr. Otto Struve as director. The principal telescope is a reflector of 82-inch aperture, second only in size to the 100-inch telescope of Mt. Wilson.

A partial list of other professional organizations which will meet in conjunction with the division are as follows:

Mathematical Association of America, southwestern section, *chairman*, R. S. Underwood, Lubbock.
Society of American Foresters, southwestern section, *chairman*, E. R. Smith, Albuquerque.
West Texas Historical and Scientific Society, *chairman*, Henry T. Fletcher, Marfa.
Texas Academy of Science, *chairman*, W. T. Gooch.
Texas Folk Lore Society.
Texas Archeological and Paleontological Society, Abilene, *chairman*, Dr. Cyrus N. Ray, Abilene.

Due to the fact that the meetings have been scheduled to coincide with the dedication ceremonies of the observatory, and that so many organizations from the eastern part of Texas will participate, the exact schedule of the program is still in the formative state. Regular features of the division meetings include the Powell Lecture, to be delivered this year by Dr. A. H. Compton, of the University of Chicago, on the topic "Physics Views the Future"; the presidential address, to be given by Dr. E. F. Carpenter, Steward Observatory, University of Arizona, and the division banquet. In addition, the Texas Academy of Science plans to hold a dinner meeting with a special speaker.

The schedule for Friday, May 5, promises to be unusually interesting with an astronomical symposium at Mt. Locke in the afternoon, a "chuck wagon" supper, and open house to the division members at the observatory that evening.

Many of the visitors will want to stay over until Saturday, May 6, to hear the symposium on "Galactic and Extra-Galactic Structures," which is being held by fourteen of the most distinguished scientists of this continent and Europe under the auspices of the observatory staff.

Field trips of special interest to biologists, geologists, anthropologists and historians are being arranged. The Big Bend of Texas is rich in early Spanish colonial history, being the region of five major Spanish expeditions. Over this is spread the events of Mexican authority, early Texas history and some of the latest conflicts of the U. S. Army and hostile Indians. Pre-history is represented by many evidences of primitive man, and in late years a large number of expeditions from archeological museums have established excavation sites of much interest to anthropologists. Within but a short distance from Alpine are to be found geologic structures of every description, as a consequence of which there is a large range in variety of life forms, all the way from those of the hot desert to those of the mountain tops.

The chairman of the Local General Committee is Victor J. Smith, director of the Big Bend Museum of the West Texas Historical and Scientific Society. C. T. Elvey is chairman of the committee in charge of activities at the observatory. Papers to be presented before the various section meetings must be in the hands of the respective chairmen of the sections by the first of April. Complete programs will be mailed to all members and all those presenting papers a week in advance of the meetings. Any special requests for programs should be sent to the secretary of the division.

V. C. KIECH,
Secretary
UNIVERSITY OF NEW MEXICO

THE AMERICAN INSTITUTE OF THE CITY OF NEW YORK AND THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

AFFILIATION of the American Institute of the City of New York was voted by the council of the American Association for the Advancement of Science at Richmond on December 27. This affiliation is on the same basis as the association's affiliated state academies. The American Institute was chartered in 1828 "for the purpose of encouraging and promoting domestic industry in New York State and in the United States."

At a subsequent meeting of the Association of State Academies, Professor E. C. L. Miller, of the Virginia Academy of Science, was authorized to appoint a committee to work with representatives of the American Institute in arranging plans whereby the American Institute may cooperate with the state academies and their junior academies in activities of mutual interest.

The American Institute conducts separate programs for each of its three groups of members. For adults it presents, popular demonstration meetings, round-table discussions, symposia, forums and dinners. Annually, since 1932, it awards its gold medal to an individual or corporation in order to "suitably recognize meritorious achievements in science, industry, engineering or architecture that have a broad incidence on human welfare." The gold medal for 1938 will be awarded to the Sperry Gyroscope Company for outstanding achievement in the design and manufacture of instruments for navigation resulting in greater safety both in the air and on the sea.

Each year, the American Institute gives one or two fellowships to "persons who have done outstanding work in the interpretation of scientific, engineering or industrial achievement which promotes effectively the knowledge and general understandng of these arts and sciences." For 1938, the fellowships are awarded to Dr. Ross A. Baker, professor of chemistry at the College of the City of New York, for the promotion of better teaching and evidence of deep appreciation of the problems of students in colleges, and to James T. Grady, director of the department of public information of Columbia University, for his pioneer work in promoting accuracy of science reporting through the press.

Separately organized within the American Institute are its associate members between 18 and 25 years of age. They have their own officers and committees, and they plan their own programs and social events. Most of them are college students or graduates already specializing in some branch of science. They take part in round-table discussions, field trips, member demonstrations and general meetings.

One of the most vital parts of the work of the American Institute is its science and engineering clubs. As described in the issue of SCIENCE for December 2, 1938, these are a recent expansion of the program it has fostered in New York City and vicinity for eleven years. New funds have become available for the work of establishing and aiding science clubs elsewhere, for assisting in organizing workshop courses, science congresses, photographic exhibits and science fairs. The official publication of the American Institute Science Clubs is the *Science Observer,* a monthly newspaper carrying columns devoted to youth research projects, up-to-date news in science and club activities.

The American Institute, now 111 years old, conducted the first New York County Fair in the Masonic Hall in New York City on October 24, 1828, to encourage manufacturers and inventors in the United States, and to bring the public's attention to the varieties and excellence of goods made in America. At its subsequent county fairs, which are still held each year as the school science and engineering fair, the American Institute introduced to the public the Morse telegraph, the Hoe press, the Mason and Hamlin organ, the McCormick reaper and the Singer sewing machine.

Congressman James Tallmadge (1778–1853) was one of the founders of the institute and was its president from 1831 to 1850. He also served as Lieutenant-Governor of New York State in 1825 and helped to found New York University. He was a staunch supporter of the Whig doctrine of the protection of growing American industry. Other distinguished officers and members famous in American history were Daniel Webster, Henry Clay, Cornelius Vanderbilt and Peter Cooper. Horace Greeley was its president from 1866 to 1871. In its early days the membership of the American Institute was from ten to fifty. It held its early meetings in Tammany Hall and later in Broad Way House. Its fairs were at one time held in Castle Gardens, now the New York City Aquarium.

AWARDS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

AT the eighty-sixth annual meeting of the American Society of Civil Engineers in New York City the Hoover Medal was presented to John Frank Stevens, formerly chief engineer of the Panama Canal. The medal was received for Mr. Stevens by his son, Donald F. Stevens, of Baltimore, a past president and honorary member of the society, superintendent of transportation of the Baltimore and Ohio Railroad. Gano Dunn, past-president of the American Institute of Electrical Engineers, made the presentation, and Ralph Budd, president of the Burlington and Quincy Railroad, spoke of Mr. Stevens's achievements.

Other medals and prizes were awarded as follows: The Norman Medal to Professor Hunter Rouse, of the California Institute of Technology; the James R.

Croes Medal to E. C. Hartman, of the Aluminum Research Laboratories of New Kensington, Pa.; the James Laurie Prize to Leon S. Moisseiff, who designed the Queensboro and Manhattan bridges and was consultant on such bridges as the George Washington, Golden Gate, Whitestone and many others.

The Arthur M. Wellington Prize was presented to Charles M. Noble, engineer, for the Pennsylvania Turnpike Commission, Harrisburg; the Collingswood Prize for Junior Engineers was presented to Douglas M. Stewart, of the Ingersoll-Rand Company, New York.

Five honorary memberships, given to outstanding engineers, were conferred on the following: C. Frank Allen, professor emeritus, Massachusetts Institute of Technology; Anson Marston, past-president of the society and dean emeritus of engineering, Iowa State College, Ames, Iowa; Arthur S. Tuttle, past president of the society, who has spent most of his life in the service of New York City in an engineering capacity; Frank E. Weymouth, general manager and chief engineer of the Metropolitan Water District of Southern California, who has just completed the Los Angeles Aqueduct, and Edward E. Wall, director of public utilities for St. Louis, who was represented by F. G. Jonah, chief engineer for the St. Louis-San Francisco Railway.

SCIENTIFIC RESEARCH UNDER THE FEDERAL GOVERNMENT

ACCORDING to an Associated Press dispatch, President Roosevelt commended "to the consideration of the Congress" on January 23 a compilation of the activities of federal agencies in the field of research.

The report, prepared by the National Resources Committee, discussed federal research in medicine, agriculture, economics, public administration, etc. It suggested the coordination of such efforts.

Mr. Roosevelt's message follows:

I transmit herewith for the information of the Congress a report entitled "Research—A National Resource" compiled by the National Resources Committee.

This report deals with the relation of the Federal Government to research. Subsequent reports in this field will cover research by colleges, universities and foundations, by business organizations, by the industrial laboratories and by the state and municipal governments.

The dependence of civilization on science is universally recognized, but the extent of the activities of private and public agencies carrying on scientific inquiry is not generally known. It is unlikely that large numbers of our people have any adequate realization of the services which are being rendered by the executive agencies of the Federal Government through scientific researches in medicine, agriculture, economics, public administration and the other natural and social sciences.

This report indicates the new emphasis in recent years on activities in the social science fields and stresses the need for effective coordination of all agencies engaged in research in order to achieve the solution of many of our more difficult problems.

I commend the report to the consideration of the Congress.

In the report, the committee recommended these steps:

Further studies on work of the advisory committees which cooperate with federal research agencies and on research being done by states and municipalities.

Improvement in methods of recruiting research workers for government service.

Authorization for government research agencies to contract for cooperation with recognized private research organizations.

Financial support for international scientific meetings and encouragement of American participation in them.

Organization of government research so as to avoid the possibilities of bias.

Encouragement of decentralized research outside of the government.

Further interrelation of governmental research agencies by organization of central councils similar to those formed by private research.

SCIENTIFIC NOTES AND NEWS

DR. EDWARD R. WEIDLEIN, director of the Mellon Institute, Pittsburgh, Pa., has been presented with a Meritorious Service Medal of the State of Pennsylvania for "his outstanding contributions to industrial science."

DR. ARNO B. CAMMERER, director of the National Park Service, received the gold Cornelius Amory Pugsley Medal for park service in 1938 at the forty-fourth annual meeting in New York City on January 16 of the American Scenic and Historic Preservation Society.

THE Oersted Medal of the American Association of Physics Teachers, established through the generosity of an anonymous donor, was awarded for 1938 to Professor Alexander Wilmer Duff, professor emeritus of physics at the Worcester Polytechnic Institute. The award was made at the annual meeting of the American Association of Physics Teachers in Washington, D. C., on December 30.

THE Robert W. Hunt Award of the American Institute of Mining and Metallurgical Engineers for 1939 will be made to K. C. McCutcheon and John Chipman for their paper on "Evaluation of Gases from Rimming-Steel Ingots." The award of the Institute of Metals Division will be made to Frederick N. Rhines and Robert F. Mehl in recognition of their

paper on "Rates of Diffusion in Alpha Solid Solutions of Copper."

THE Duddell Medal of the Physical Society, London, has been awarded to Robert W. Paul in recognition of his work in the manufacture of electrical measuring instruments and in the development of the cinematograph.

DR. ARNAUD DENJOY, professor of mathematics at the University of Paris and exchange professor at Harvard University for the current academic year, has received the Prince de Monaco Prize from the Academy of Science of the Institut de France. The prize, which was established in 1924 by Prince Albert I of Monaco, carries an award of 100,000 francs and is given in recognition of distinguished work in the field of mathematics.

DR. MAX BODENSTEIN, professor of physical chemistry at the University of Berlin, has been elected an honorary member of the Swiss Chemical Society.

DR. GEORGE W. LEWIS, since 1924 head of the aeronautical laboratories at Langley Field, Va., and research director of the National Advisory Committee for Aeronautics, has been elected president of the Institute of Aeronautical Sciences. He succeeds T. P. Wright, vice-president and director of engineering of the Curtiss-Wright Corporation.

THE following have been elected officers of the College of Physicians of Philadelphia for the year 1939: *President,* George P. Muller; *Vice-president,* Edward B. Krumbhaar; *Secretary,* J. Harold Austin; *Treasurer,* T. Grier Miller; *Honorary Librarian,* Albert P. Brubaker; *Censors,* George E. de Schweinitz, John H. Gibbon, Thomas R. Neilson and Francis R. Packard; *New Councilors,* Eugene P. Pendergrass and Truman G. Schnabel.

AT the annual meeting in Toronto on January 17 of the Royal Astronomical Society of Canada officers were elected for 1939 as follows: Dr. William Findlay, professor of mathematics, McMaster University, Hamilton, Ontario, was reelected president. Dr. J. A. Pearce, Dominion Astrophysical Observatory, Victoria, B. C., and Dr. Frank S. Hogg, David Dunlap Observatory, University of Toronto, were elected vice-presidents. E. J. A. Kennedy, Toronto, was elected general secretary, and J. H. Horning, Toronto, treasurer.

W. REDMOND CROSS, president of the New York Zoological Society, has been elected chairman of the council of the American Geographical Society of New York. He succeeds Philip W. Henry, who resigned recently after serving for seventeen years.

AT the seventieth annual meeting of the board of trustees of the American Museum of Natural History, F. Trubee Davison was reelected president of the board. A. Perry Osborn was elected first vice-president. Mr. Osborn, a son of the late Professor Henry Fairfield Osborn, has served as trustee for eighteen years and has been executive chairman of the ten-year development program since its inception in February, 1937. Other officers reelected include: Cleveland E. Dodge, *second vice-president;* E. Roland Harriman, *treasurer,* and Clarence L. Hay, *secretary.* J. P. Morgan resigned as a trustee after a service of thirty years. During his trusteeship he has been vice-president, a member of the finance committee, of the buildings and plans committee, of the nominating committee, of the executive committee and of several special committees.

DR. WALTER DILL SCOTT, since 1920 president of Northwestern University, has presented his resignation to the trustees. He expressed the hope that his successor might be elected so as to permit his retirement in the autumn. Before becoming president, Dr. Scott had been connected with the university since 1900, successively as instructor, assistant professor and professor of psychology and director of the psychological laboratory.

DR. EDWIN COOPER VAN DYKE, since 1913 professor of entomology at the College of Agriculture of the University of California, will retire at the close of the academic year.

DR. WILLARD C. FLEMING, assistant dean of the College of Dentistry of the University of California, will become dean of the college at the conclusion of the present college year.

AT Western Maryland College S. B. Schofield, professor of chemistry and formerly dean of the college, has been appointed to the newly created position of dean of administration, and Dr. L. M. Bertholf, professor of biology and formerly dean of freshmen, has been appointed dean of the college.

DR. NORMAN CAMERON, associate in psychiatry in the Johns Hopkins Medical School and resident psychiatrist in the Johns Hopkins Hospital, has resigned to take charge of the laboratory for experimental psychology and psychopathology at the Payne Whitney Clinic of the New York Hospital. He has been appointed associate professor of psychology in the Cornell University Medical College and assistant attending psychiatrist in the New York Hospital.

PROFESSOR RAYMOND L. TAYLOR, associate professor of biology at the College of William and Mary, has been appointed Kenan visiting professor in the department of zoology of the University of North Carolina for the remainder of the present college year.

IT is announced in *Nature* that Dr. Erwin Schrödinger, professor of theoretical physics at the University

of Graz, Austria, has been appointed by the Fondation Francqui as a visiting professor for the next six months to a "Chaire Franqui" in the University of Ghent.

DR. CHARLES F. NASSAU, chief surgeon of Frankford Hospital and clinical professor of surgery at the Jefferson Medical College, has been appointed director of public health in Philadelphia.

DR. TREVOR KINCAID, chairman of the department of zoology of the University of Washington, has become a member of the staff of the Oceanographic Laboratories at Friday Harbor. He will offer a course on marine plankton during the regular summer session, from June 19 to August 19.

SIR FRANK E. SMITH will relinquish on January 31 his position as secretary to the Committee of the British Privy Council for Scientific and Industrial Research. The King has approved the appointment of Dr. E. V. Appleton, Jacksonian professor of natural philosophy in the University of Cambridge and fellow of St. John's College, to succeed Sir Frank.

THE *Lancet* states that Professor Julius de Darányi, director of the Hygiene Institute of the Royal Hungarian Péter Pázmány University of Budapest, has been appointed president of the Hungarian Postgraduate Medical Education.

DR. WILLIAM FINDLAY, McMaster professor of mathematics at the University of Toronto, gave on January 24 his address as president of the Royal Society of Canada. The address was entitled "Mathematics and Astronomy."

DR. WILLIAM R. AMBERSON, professor of physiology at the School of Medicine of the University of Maryland, spoke at a meeting on January 27 of the Philadelphia Branch of the American Association of Scientific Workers on "Cooperative Farming in American Agriculture."

THE Regius professorship of surgery in the University of Glasgow will become vacant on October 1, owing to the expiration of the tenure of office of Professor Archibald Young. Applications for the chair should be addressed to the Private Secretary, Scottish Office, Whitehall, London, S.W.1, and should reach him not later than March 15.

CORNELL UNIVERSITY has announced the establishment of the Henry Strong Denison graduate fellowships in agriculture, in memory of Henry Strong Denison, a graduate of Cornell University in the class of 1905. These fellowships were created by a gift from the Henry Strong Denison Medical Foundation, Inc., founded by Mrs. Ella S. Denison. Three fellowships with an annual stipend of $1,000 each will be awarded in the fields of the plant sciences, animal sciences and social sciences and agricultural engineering, for the purpose of encouraging young graduate students "who are especially gifted and qualified to carry on research work in the science of agriculture." Applications must be filed in the office of the Graduate School before March 1.

E. I. DU PONT DE NEMOURS AND COMPANY will award six post-doctorate fellowships for fundamental research in organic chemistry and eighteen post-graduate fellowships for research in the field of chemistry for the academic year 1939–40. The post-doctorate fellowships are for $2,000 each, while the eighteen post-graduate fellowships are for $750 each. Fellowships to cover advanced work in the field of chemistry have been made for a number of years by the du Pont Company. The purpose of the plan is to promote the advancement of science and to cooperate with the educational institutions in their efforts to carry on advanced research work. These fellowships do not restrict research to subjects connected with the products of the company. The colleges select not only the beneficiary of the fellowships, but also the subject of the research.

AWARDS from the Elizabeth Thompson Science Fund were reported in SCIENCE on May 20 and earlier. The next meeting of the trustees will be held in April. Applications for grants should be made to the Secretary, Dr. Jeffries Wyman, Jr., Biological Laboratories, Harvard University, Cambridge, Mass.

THE University of California has received gifts amounting to $122,000. This sum includes: from the estate of John E. Cox, $63,085 for medical research; from the estate of William Wilson Karson, for the university hospital, $50,000; from the Rockefeller Foundation, for the radiation laboratory, $3,750; for the Institute of Child Welfare, $3,490; for the research of Herbert M. Evans, $3,750; for the Institute of Social Sciences, $2,500; from the Fruit Growers Supply Company of Los Angeles, $2,500 for research in orchard heating by the division of agricultural engineering at Davis.

DR. H. A. B. DUNNING, director of the research laboratory and president of Hynson, Westcott and Dunning, Baltimore, has given $50,000 toward the construction of a research laboratory for the department of science of Washington College, Chestertown, Md. An initial gift of $50,000 towards the library was made some time ago by Dr. George A. Bunting, of Baltimore.

MISS ANNIE-MAY HEGEMAN, of New York and Lenox, Mass., has given to the Library of Congress and the Smithsonian Institution the sixteen-room residence of her stepfather, the late Representative Henry Kirke Porter, of Pennsylvania. Asking that the funds from the sale of the property at Sixteenth and I Streets, Northwest, be recorded as a memorial to

Mr. Porter, Miss Hegeman directed that the money be divided equally between the two institutions and used for the "increase and diffusion of knowledge."

THE late Charles E. Munroe, who was the last surviving charter member of the American Chemical Society, has left to the George Washington University, Washington, D. C., his library on chemistry and explosives, consisting of 505 bound volumes, 2,627 unbound volumes and pamphlets, and some thousands of clippings.

CAPTAIN ALLAN HANCOCK has presented the exploration cruiser *Velero III* to the University of Southern California. The vessel and its endowment go to the university as companion gifts to the Allan Hancock Foundation for Scientific Research established a year ago, a building for which is now being constructed. All steel from stem to stern the *Velero III* is 198 feet in length with 30-foot beam, powered by twin Diesel engines and fuel capacity for a 10,000-mile non-stop cruise. Fresh food and water storage is ample to supply thirty men on a three-months voyage. For the past eight years annual voyages have been made in the eastern Pacific. The vessel will continue her exploration work and will also serve for instructional purposes in nautical subjects.

IT is stated in *Nature* that the annual report of the Institute for Science and Labor, which was transferred from Kurasiki to Tokyo at the end of 1936, indicates that much of the work of the institute follows the lines of work of the National Institute of Industrial Psychology in Great Britain. Among a number of completed researches mentioned in the report are those on the clothing of farmers, syphilis morbidity in villages, psychological qualifications for textile workers, an examination of vocational testing methods, studies on manual dexterity and on the physical fitness of employees, studies on motions and positions in working, on repetition work, psychological differences between skilled and unskilled workers in a weaving factory. Some of the physiological work is on lines similar to those pursued by the Industrial Health Research Board in Great Britain as, for example, the investigations on environmental conditions, such as climate, the effect of occupational activities on basal metabolism, the metabolism of heavy muscular labor or the physiological studies on walking, but in addition the institute has completed a preliminary research on the daily protein requirements of the nation. Occupational diseases and the prevention of accidents have also received attention, and it is noted in abstracts of publications of the institute included in the report that scientific workers in Japan are now advocating on scientific grounds raising the minimum age of juvenile labor to at least fourteen years, with special protection up to eighteen years of age.

DISCUSSION

UNDERTOW[1]

IN a recent article[2] Professor O. F. Evans contributed some interesting data in regard to undertow. He showed by means of colored water that in small bodies of water with an on-shore wind there was a return of a subsurface current to counteract the on-shore current at the surface. These movements were all slow and were all observed in relatively smooth water. However, Evans suggested that these currents might become strong under storm conditions producing an "undertow" which might be dangerous to bathers.

Previously Shepard (SCIENCE, 84: 181–82, 1936) had suggested that this dangerous "undertow" was probably a myth based on the existence of river-like currents which move perpendicularly out from the beach in many localities. These flows, which are called "rip currents" or "rip tides" are in no sense undertow since like streams their principal movement is in the upper water. The existence of dangerous "undertow" was questioned chiefly because of failure to obtain reports from life guards or swimmers that it existed, and also because, as Professor W. M. Davis (SCIENCE, 61: 206–08, 1925) had shown, wave motion produces both a forward and backward movement along the bottom. However, in view of the experiments cited by Evans it seemed highly desirable to make further investigation of the nature of subsurface currents, particularly under storm conditions.

The opportunity to make these tests was provided by the 1,000-foot Scripps Institution pier. For the past year the writers, with the help of WPA assistants, have been taking daily soundings along this pier, using a machine which rolls along the rail and has a sounding arm which extends out for 10 feet from the pier. To the sounding line on this machine a wooden frame like that in Fig. 1 was attached. This frame has a large vane at the bottom which is moved in the direction of the prevailing current. At the top is a smaller vane which serves to tell the direction in which the large vane is pointing under the water. A heavy weight was suspended at the bottom of the line to dampen the surge of the waves. This device could be raised or lowered to any depth desired and thus could show the nature of the water movement at the various depths. Also it could be moved all along the pier by means of

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 39.

[2] SCIENCE, 88: 279–81, 1938.

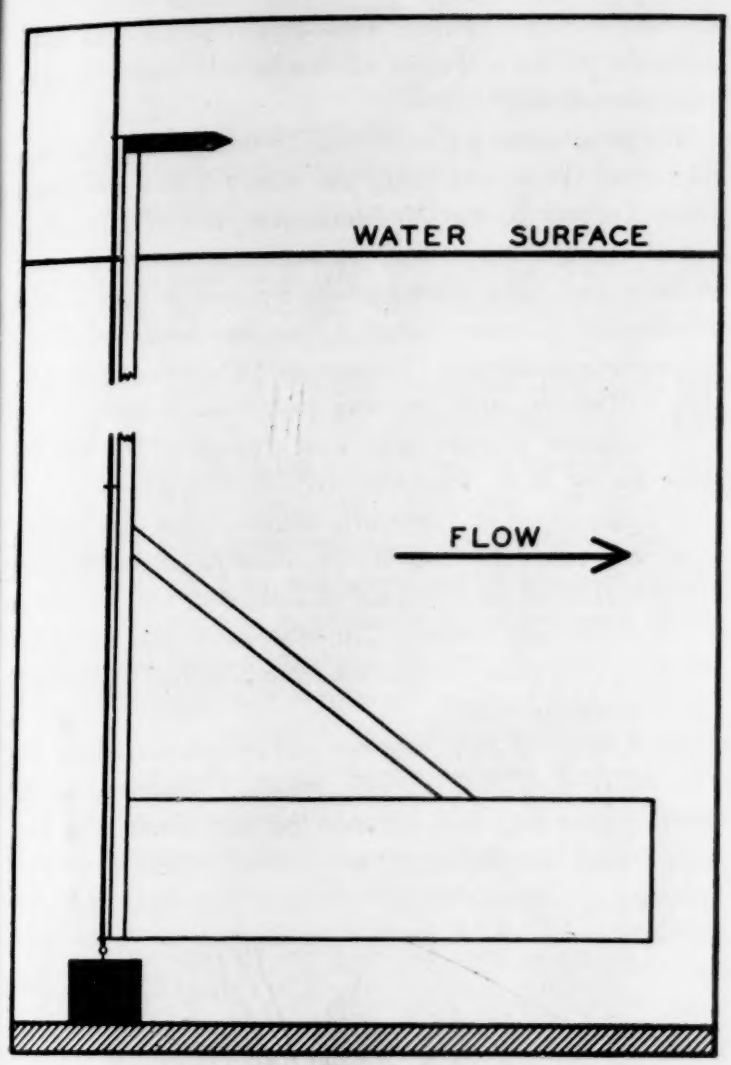

FIG. 1

the movable sounding machine. This carried observation out to depths of about 22 feet.

Choosing two days when there was a strong on-shore wind and fairly large waves numerous tests were made. The directions were easily observed and seemed to leave no doubt as to conditions existing at these times. In all cases the current was essentially the same at the surface as at the bottom. For the most part the current was moving to the south along the shore.

In some places near shore within the range of the breakers outward moving currents were observed, but these were always shown both at the surface and on the bottom. They can be considered as a type of rip current.

Observations with a current meter at the end of the pier in about 25 feet of water showed also that the current had a longshore trend in the same direction as the current at the surface. On the other hand, a bottom current, observed by R. Revelle and R. H. Fleming on another occasion when there was no wind, flowed contemporaneously with the outward movement of a rip current. On this occasion the bottom current was longshore, indicating that the rip current had passed over the bottom water without disturbing it. This of course represents a case that is the opposite of undertow.

These observations suggest that dangerous undertow is not an accompaniment of strong on-shore winds and large waves. However, they are of too limited scope to prove the absence of this danger to bathers. It is to be hoped that Professor Evans and others interested will extend these experiments to lakes and other parts of the ocean. Meantime the bather is still in danger from the rip currents which may carry him out beyond his depth, even if they do not carry him below the surface. The rip currents incidentally are observed under all sorts of conditions of waves, currents and winds.

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SURVIVAL OF THE TROPICAL RAT FLEA IN UNITED STATES

SINCE July, 1934, when Roudabush and Becker[1] reported the tropical rat flea (*Xenopsylla cheopis*) from the interior of the United States, several other reports have established its presence from the East, Mid-west and Far West. The evidence given in these papers leaves one with the impression that the flea is well established, but as yet no one has proved that the flea does not migrate into the interior every year.

Realizing that such a question must some time be answered, Dr. E. R. Becker and the author continued to collect the fleas at Ames, Iowa, every year from 1934 to 1938. In order to check its presence thoroughly, they were collected every fall until snow covered the ground and every spring as soon as possible after the first thaw. These collections prove that the flea is not a periodic visitor but is actually a resident in the interior.

In August, 1938, several specimens of the tropical rat flea were sent to Ward's Natural Science Establishment for identification. These came from Youngstown, Ohio, and since Ewing and Fox[2] have already reported that infestation no further details are necessary.

Several workers, cleaning out an infestation of insects in a Rochester, N. Y., church, brought into Ward's some of the insects for identification. Among other things three female specimens of the flea under consideration were found in a chandelier of the inverted dome type. Exactly how or why the fleas happened to be there is not understood, but there is some evidence that at least one of them underwent some development while in the chandelier, since a deserted pupal case was found in the debris.

Ewing and Fox[2] state that "there is a possibility that a more resistant race of this flea has been devel-

[1] R. L. Roudabush and E. R. Becker, SCIENCE, 80: 97, 1934.

[2] E. W. Ewing and Irving Fox, SCIENCE, 88: 427, 1938.

oped in some of our northern ports, such as New York and Boston and from there has spread to the Central states." Such a hypothesis is unnecessary. Freed, Jordan and Eckhoff[3] in reporting a case of endemic typhus fever in Des Moines, Iowa, sent the arthropods collected from rats in that locality to the author for identification. This material revealed the presence of *Xenopsylla cheopis, Liponyssus bacoti* and a species of *Hoplopleura* among other things. Dr. G. F. Ferris[4] identified the *Hoplopleura* as *H. oenomydis,* a species which has never been recorded in North America. The report by Freed, Jordan and Eckhoff established the fact that rats with their parasites might have been imported from the southern states, but since *H. oenomydis* has not even been found there it is just as logical to assume that the rats were imported directly to Des Moines.

Thus it is felt that the spread of the flea could have been more easily accomplished by shipping on the Mississippi than by the cross-country travel from New York and Boston. This, accompanied by the fact that in most cases years and years of gradual exposure are necessary to create a race more resistant to cold, would appear to leave the hypothesis of Ewing and Fox without a basis.

Further, a brief thought on the subject should account for the survival of the flea in the colder temperatures of the temperate zone. It matters not how low the temperature falls as long as the flea, its larvae and eggs remain in the warm confines of the rat's tunnel. The same warmth which allows the rat to live can also keep the flea alive. In other words, a flea in a test-tube exposed to freezing temperatures is not any more at home than man deprived of his home, his clothing and his food, but we have long since ceased to marvel because man can survive freezing temperatures in his artificial environment.

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REDISCOVERY OF THE RHIZOCEPHALAN PELTOGASTER PAGURI ON THE NORTH AMERICAN COAST

FOR more than a century, the Rhizocephala, a group of degenerate parasitic Cirripedes, has engaged the attention of many European zoologists, but, with the exception of a few Sacculinidae described from the West Indies, there have been no studies made of these remarkable Crustacea from the Atlantic coast of North America. During July, 1938, at the University of Maine Marine Laboratory on Frenchmans Bay, Maine, I had the good fortune to discover a representative of the order Rhizocephala, *Peltogaster paguri* Rathke, parasitic on the abdomen of the hermit crab *Pagurus pubescens* Kröyer.

The geographical distribution of this parasite is considerable. It occurs along the entire European coast from Norway to the Mediterranean but is strictly a boreal species, more rare toward the southern edge of its range. Its chief host in Europe is *Eupagurus bernhardus* (Linneus), but it has also been found on *Eupagurus cuanensis* (Thompson), *Pagurus chiracanthus* Lilljeborg, and *Pagurus pubescens* Kröyer.

Peltogaster paguri was first recorded for North America by A. S. Packard, Jr.[1] (1866), who found a single specimen at Eastport, Maine. Another specimen was taken by the W. A. Stearns expedition at Henley Harbor on the coast of Labrador and recorded by S. I. Smith[2] (1884). In both cases the host was likewise *Pagurus pubescens.* No further American records are known.

Of a total of 341 *Pagurus pubescens,* consisting of 128 males and 213 females, which I examined from Frenchmans Bay this summer, 86 individuals (25 per cent.) bore the parasite *Peltogaster.* These were distributed as follows:

33 males, each carrying one Peltogaster
4 males, each carrying two Peltogaster
45 females, each carrying one Peltogaster
3 females, each carrying two Peltogaster
1 female, carrying three Peltogaster

The largest parasite obtained measured 21 × 12 mm, the average size being about 13 × 5 mm.

In many instances the Rhizocephalan was itself parasitized by another crustacean, one of the Epicaridea, *Liriopsis pygmaea* (Rathke). This isopod hyperparasite is new to American waters, but has been known as occurring on the same host along the coast of Northern Europe.

There are only two species of hermit crabs commonly found in Frenchmans Bay, the *P. pubescens* already mentioned and *P. acadianus* Benedict. Both occur on hard bottoms from near low water to 90 feet, with the former more common toward the outer bay and on the open coast, the latter more prevalent in the inner bay. It is significant that none of the 26 males and 46 females of *P. acadianus* which were examined, a goodly number from the same collecting grounds that yielded parasitized *P. pubescens,* showed any evidence of *Peltogaster.*

Abundant material to elucidate the embryonic development and larval stages of *Peltogaster,* the anatomy and life history of the imperfectly known *Liriopsis* and the effect of these parasites on their

[3] H. Freed, C. F. Jordan and D. Eckhoff, *Jour. Ia. State Med. Soc.,* 27: 425–426, 1937.
[4] G. F. Ferris, personal communication, 1937.

[1] A. S. Packard, *Mem. Bost. Soc. Nat. Hist.,* v. I, p. 295, 1866.
[2] S. I. Smith, *Proc. U. S. Nat. Mus.,* v. 6, p. 222, 1884.

hosts has been collected and will be reported on elsewhere.

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NOMENCLATURE OF GONAD-STIMULATING HORMONES OF PLACENTAL ORIGIN

WE have recently obtained evidence[1] indicating that the rat may be added to a growing list of mammals whose foetal placentae secrete some type of gonad-stimulating hormone. By combining the evidence which has been accumulated from the horse, human being, monkey, chimpanzee and rat[2] it becomes apparent that the natural function of these chorionic secretions is to prolong corpus luteum function during pregnancy, and there is indirect evidence that a similar mechanism is operative in the mouse, rabbit and hamster.[3] This concept has been obscured, however, by the fact that when administered to foreign species, the known substances display great differences in the type of gonadal response which they produce.

These gonadotropic substances which arise from or are associated with the products of pregnancy are known by terms that in most cases are ambiguous and unduly cumbersome. Certainly the policy of using the name of a body fluid to designate a hormone, as for instance "pregnant mare serum" or "the urine of pregnant women," etc., is an example in loose terminology. It seems to us that in view of the fact that these hormones have a common tissue source and exercise a homologous function, the introduction of a generic term would conform to the facts and afford a satisfactory basis for a sound nomenclature.

We therefore propose that the term *cyonin* (Gr. kuo – pregnancy + hormone + protein) be applied to all those hormones of chorionic origin and of protein nature which act to sustain a female sex hormone balance favorable to the maintenance of pregnancy. This word used in conjunction with the name of the animal in which the hormone occurs would apply to any mammals where such a substance might exist. Thus "human cyonin" would replace such terms as "pregnancy urine," "pregnancy prolan" and "anterior-pituitary-like hormone" and "equine cyonin" such terms as "pregnant mare serum" and "endometrial scrapings of the mare," while "murine cyonin" would apply to the recently described placental hormone of the rat. Should more than one hormone be active in a given species, then qualifying terms may be added.

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[1] E. B. Astwood and R. O. Greep, *Proc. Soc. Exp. Biol. and Med.*, 38: 713, 1938.

[2] H. H. Cole and G. H. Hart, *Am. Jour. Physiol.*, 93: 57, 1930; J. S. L. Browne and E. M. Venning, *Lancet*, 2: 1507, 1936; *Am. Jour. Physiol.*, 123: 26, 1938; R. E. Kirsch, *Am. Jour. Physiol.*, 122: 86, 1938.

[3] W. H. Newton, *Jour. Physiol.*, 84: 196, 1935; G. P. Heckel and W. M. Allen, SCIENCE, 87: 302, 1938; M. Klein, *Arch. Anat. Micr.*, 31: 397, 1935, *Arch. d'Anat. d'Histol. et d'Embryol.*, 18: 1, 1934 and *Proc. Roy. Soc.*, B. 125: 348, 1938.

SCIENTIFIC BOOKS

CRYSTAL PHYSICS

A Text-book on Crystal Physics. By W. A. WOOSTER. Cambridge: At the University Press; New York: The Macmillan Company. xxii + 295 pp., 108 diagrams, $4.00.

IT seems that ever since Laue's discovery of x-ray diffraction crystallographers have been too busy to present an up-to-date treatment of those physical properties of crystals which are determined by microscopic rather than molecular symmetry. The experimental physicist and engineer interested in such properties as elasticity and piezoelectricity had to refer to the authoritative but cumbersome "Lehrbuch der Kristallphysik" by Woldemar Voigt, which was published in 1910 and was never translated into English.

In the foreword to a new printing of Voigt's book in 1928 Professor von Laue stated that the phenomenological theory of crystals could be greatly simplified by using the notation for components of higher-order tensors which the general theory of relativity has introduced into physics. He concluded that "whoever wants to make an improvement in that direction will have to write an entirely new book. But who among present-day physicists would delve into this subject with as deep an affection as W. Voigt?"

Dr. W. A. Wooster, of the Department of Mineralogy at the University of Cambridge, has finally taken up the challenge. He can be assured of the grateful interest of physicists and metallurgists as well as crystallographers and mineralogists. The fact that Wooster's book is very modest compared to Voigt's both in volume and in price will increase its appeal. The book is intended primarily as a text-book for students at universities, and presupposes "a knowledge of the elements of physics, mathematics and crystallography." "A two-fold object has been kept in view

—to present the classical treatment of the physical properties of crystals in terms of tensor notation and also to indicate the lines of development of modern theoretical and experimental research."

In the preparation expected of the reader as well as in the choice of the material treated the standpoint of the *mineralogist* prevails perhaps more strongly than would be indicated by the title and the author's preface. The physicist among the readers will easily find the necessary crystallographic information elsewhere; but the dearth of mathematical training presupposed forces the author to forsake the elegance of treatment which he could give to his subject on a more solid foundation of mathematical physics. On the other hand, a reader who does not even know about scalar and vector products will hardly be able to comprehend at all the transformation theory of higher-order tensors.

The greatest asset of the book is the close correlation between theory and experimental results given at each step of the development. Wherever possible, it is shown how the amount of observed physical anisotropy is connected with the atomic structure type of the substance. Although for most physical properties such considerations are still in a semi-quantitative state they show most impressively how much our understanding of the properties of solid matter has been advanced by x-ray structure analysis. Experimental methods are explained in principle, but the limited space does not permit detailed descriptions. A fuller selection of references to experimental procedures would have been very useful.

The general plan of the book is to treat in succession the phenomena which are described by a second-order tensor, a third-order tensor and a fourth-order tensor, respectively.

Chapter I (14 pages) contains the fundamentals of tensor notation and the limitations imposed by crystallographic symmetry on properties described by a second-order tensor.

Chapter II (48 pages) is entitled "Homogeneous Deformation; Thermal Expansion and Plastic Deformation." Chapter III (31 pages) is devoted to heat conduction and thermoelectric effects. The treatment of these fields, to which the author has made important original contributions, is excellent; much of the material presented will be new to most physicists. Electric conductivity of metallic crystals is dealt with very briefly; electric currents in semi-conductors and insulators are outside the scope of the book.

In Chapter IV, 33 pages deal with para- and diamagnetism. Detailed consideration is given to the determination of molecular susceptibilities of aromatic compounds. Dielectric phenomena are treated in eleven pages. The account of the electric properties of Rochelle salt disagrees at various points with more recent experimental results, especially those of the Zurich school and of H. Mueller, of the Massachusetts Institute of Technology.

Chapter V (60 pages), "Some Problems in Crystal Optics," is not intended as a systematic treatment of that great field but rather as a critical appendix to existing treatises on mineralogical optics. A good account is given of the beautiful work of W. L. Bragg, Hylleraas and others on the calculation of double refraction from atomic arrangement.

In Chapters VI (35 pages), "Piezoelectricity," and VIII (44 pages), "Elasticity," the advantages of tensorial notation are most apparent. The specialization of the matrices of piezoelectric and elastic constants for the different crystal classes is carried through in a straightforward way for all except the trigonal and hexagonal classes; for these an outline of the rather complicated proof is given. The methods used in the experimental determination of piezoelectric and elastic moduli are discussed; however, there is no rigid treatment of any case of inhomogeneous deformation. The account of applications of piezoelectric crystals is on a quite elementary level; it comes rather as an anti-climax to the preceding complicated mathematical derivations.

Chapter VII (9 pages), "Pyroelectricity," does not entirely remove the confusion which has been created by the unfortunate terms "false" and "true" pyroelectricity. After discussing the electric charges produced on quartz crystals by non-uniform heating, Wooster continues: (p. 227): "When the temperature of the crystal becomes uniform the stresses are much reduced (though not zero) and hence the charges also become much less." In the opinion of the reviewer this statement is not correct. A *uniform* change of temperature will produce no *stress* at all in any crystal. For a crystal without a singular polar direction like quartz the thermal *strains* are of such symmetry that *no* electric moment results.

The magnetic analogue to pyroelectricity, ferromagnetism, is not treated at all, although in no field of modern physical research have considerations of crystal symmetry been more fertile.[1]

A book covering a territory on the borderline between two branches of science can not possibly satisfy *all* the demands of its various readers. Wooster's "Crystal Physics" can be recommended as a most valuable supplement to existing text-books on mineralogy and crystallography and deserves the attention of every one engaged in crystal research.

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[1] See for instance: F. Bitter. Introduction to Ferromagnetism, N. Y., 1937. Chapters V–VII.

INSECTS OF SUBTROPICAL FRUITS

Insects of Citrus and Other Subtropical Fruits. By HENRY J. QUAYLE. Comstock Publishing Company, Inc., Ithaca, N. Y. 1938. vii + 583 pp. Figs. 377. $5.00.

THIS treatise meets a need that has long been recognized by entomologists and fruit-growers who reside in subtropical regions. The significance of this statement will be appreciated particularly by individuals who have moved from temperate regions and engaged in the growing of subtropical fruits or engaged in pursuits dependent upon subtropical horticulture. Owing to the year-round mild temperature and the evergreen, everbearing, succulent nature of citrus and certain other subtropical fruits, insect control presents a more complicated problem than that known to the grower of deciduous fruits in temperate regions. The fight against insects infesting leaves, fruit and branches is continuous throughout the year in the growing of subtropical fruits. Treatments are rather expensive. In most districts at least one treatment annually must be made to citrus to control scale insects. A spray treatment costs about $25.00 an acre, and a fumigation treatment costs about $35.00 an acre. It behooves the grower to know the various insects, their life history and seasonal history, their degree of susceptibility or immunity to given insecticides, their natural enemies introduced and propagated by state and county agencies, and to know the facts and principles underlying or governing the effectiveness of insecticides and the application of insecticides.

For many years orchardists as well as entomologists, horticultural inspectors and pest control operators have had but limited sources from which to secure knowledge on the biology of insects affecting subtropical fruits and the diverse facts, concepts and practices concerned with the control of such pests. The most comprehensive treatise prior to Professor Quayle's book was "Insects Affecting the Orange," by H. G. Hubbard, a publication of 227 pages by the U. S. Department of Agriculture that appeared in 1885.

Professor Quayle has been an authority in the particular field for upwards of thirty years. In addition to notable work done in California, he has made two trips around the world on missions concerned with citrus insects. Coincident with the discovery of the Mediterranean fruit-fly in Florida and the work of eradicating it in 1929–30, he made a special survey of this pest in South Africa and the Mediterranean region. Appropriately, the book is world-wide in scope. The comparisons made of insect infestations in different regions and in relation to climatic conditions are of particular interest. The citrus insects of California have received special consideration. This is appropriate because in California pioneer work has been done in citrus fumigation, spraying, dusting, biological control, inspection and regulation.

The book has eighteen chapters. Chapter I gives brief characterizations of the various subtropical fruits, brief facts on the commercial production of such fruits in various parts of the world, a list of the principal insect pests of each fruit and a key to the principal citrus fruit insects and mites of the United States. Chapters 2 and 3 deal with citrus insects and mites of major importance, and Chapter 5 deals with citrus insects and mites of minor importance. Chapter 4 comprises a tabulated list of 33 species of Coccinellid beetles and 135 species of hymenopterous parasites that attack insects and mites of subtropical fruits. The tables also give data on host, stage attacked, region of the world from which the species was first obtained and citations to pages in the book where the species is discussed or referred to. One chapter each is devoted to insects and mites of the following crops: avocado, vinifera grape, Persian walnut, almond, pecan, fig, olive and date. Chapter 14 treats of insects of the oriental persimmon, the pomegranate and the sweet cherry. Chapter 15 deals with rodents, nematodes and snails; Chapter 16 with fumigation; Chapter 17 with spraying and dusting; and Chapter 18 with domestic plant quarantines that pertain to subtropical fruit insects.

The book is rich in illustrations of high quality. The text figures number 377, but the individual illustrations probably are several hundred in number, since in many instances several illustrations are included in a single text figure. The value of the book is greatly enhanced by the footnote references to the principal publications dealing with the topics discussed. The very complete index, comprising 27 pages and having subtropics indicated under principal topics, deserves special mention. For example, under the topic Oil Spray are listed page references to 36 subtopics on oil sprays. The book is substantially and attractively bound. The quality of paper and printing craftsmanship are excellent.

While the book is written primarily for the use of growers of subtropical fruits and persons engaged in entomological work concerned with this type of horticulture, it contains a great deal of information that should be interesting to entomologists in general and even to the general reader. The history of fumigation with deadly hydrogen cyanide gas and the details of the practice of this method of citrus insect control, extensively employed for the past fifty years, is intensely interesting. Equally interesting are the facts of biological control and the methods employed by some fifteen insectaries in California in rearing and releasing annually millions of parasitic and predaceous insects which attack the injurious insects.

RALPH H. SMITH

SPECIAL ARTICLES

AN ESTIMATE OF THE MAXIMUM VALUE FOR THE MOLECULAR WEIGHT OF THE TOBACCO MOSAIC VIRUS PROTEIN

DATA obtained by ultracentrifugal studies reported by Inga-Britta Erikson-Quensel and The Svedberg[1] and by R. W. G. Wyckoff, J. Biscoe and W. M. Stanley[2] indicate that the molecular weight of the infectious unit of tobacco mosaic virus is of the order of 1.7×10^7. Independent values of the particle weight normally may be obtained from diffusion studies, and H. Neurath and A. M. Saum,[3] using a virus preparation supplied by Stanley, found a diffusion constant of 3×10^{-8}. The implied molecular weight is unreasonably large, although by correcting for the shape of the particle,[4] a value of 41 million was obtained.

Curve B, Fig. 1, was obtained from a diffusion study[5]

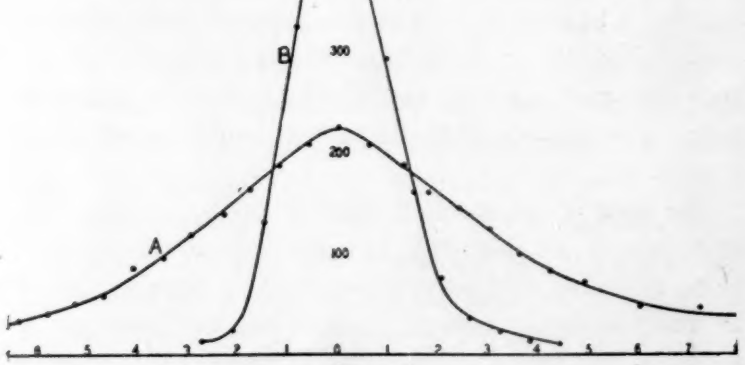

FIG. 1

of a virus preparation obtained by the method used by B. M. Duggar at the University of Wisconsin. It will be noted that the curve is skewed, and it is skewed toward the solvent side. The suggestion is that Fick's law is not followed. On the abscissa are plotted the distances from the boundary in 10^{-1} millimeters, and on the ordinate are plotted the displacements of the scale lines in microns. The time for this particular run was 343,000 seconds. An approximate value for the diffusion constant of 4.5×10^{-9} was obtained from these data following the method suggested by Lamm.[6] As this value is considerably lower than the diffusion constant obtained by Neurath and Saum, one would presume that the difference may be attributed in part to an aggregation of the protein particles induced by the heat treatment called for in the Duggar method. Bawden and Pirie[7] also voice the opinion that the heat treatment induces an aggregation. A diffusion constant of 4.6×10^{-7} was obtained from the data presented in curve A of Fig. 1. These data were obtained from a diffusion study of the same protein preparation, indicated above, dispersed in 6 M. urea + .1 M. phosphate buffer at pH 7. The time for this particular run was 58,080 seconds. The diffusion studies were started after the protein had been in the urea solution for 24 hours.

An increase in diffusion constant from 4.5×10^{-9} to 4.6×10^{-7} is induced by dispersing the virus protein in 6 M. urea. An appreciation of the magnitude of the decrease in particle weight implied in this tremendous increase in diffusion constant is obtained when it is recalled that the relation between the diffusion constant and the radius of a spherical particle given by the Stokes-Einstein equation is

$$kT/6\pi nr = D$$

k = Boltzmann constant
T = Absolute temp.
n = viscosity
r = radius of particle
D = diffusion constant

and that it is assumed that for spherical particles the particle weight varies with the cube of the radius.

A comparison of the biological activity of the virus that had stood in 6 M. urea + .1 M. phosphate buffer and the normal virus in .1 M. phosphate buffer at pH 7 is of particular interest. Data given in Table 1

TABLE 1

Hours in urea	Number of lesions per leaf		
	Concentration of protein in gr/cc		
	3×10^{-5}	3×10^{-6}	3×10^{-7}
0	4.6	1.5	.12
27	5.9	.54	.4
51	7.6	2.2	.12
75	4.1	1.7	.12
96	4.5	2.7	.4
150	1.2		

were obtained by the local lesion method of Holmes.[8] *N. glutinosa* plants were used as test plants; an average of 25 leaves were used for each test. The urea solutions were diluted greatly immediately preceding inoculation.

Inasmuch as the "molar" concentration of the virus in the presence of urea was appreciably greater than in the phosphate buffer alone, it is surprising that there was not a corresponding increase in the number of local lesions produced on the test plants.

Comparative viscosity studies of this same protein

[1] Inga-Britta Erikson-Quensel and The Svedberg, *Jour. Am. Chem. Soc.*, 58: 1863, 1936.

[2] R. W. G. Wyckoff, J. Biscoe and W. M. Stanley, *Jour. Biol. Chem.*, 117: 57, 1937.

[3] In press.

[4] Vernon L. Frampton and H. Neurath, SCIENCE, 87: 468, 1938.

[5] We are greatly indebted to H. Neurath for the privilege of using the Lamm diffusion apparatus he assembled at Cornell University.

[6] O. Lamm, *Zeits. Phys. Chem.*, 143A: 177, 1929.

[7] F. C. Bawden and N. W. Pirie, *Proc. Roy. Soc. London*, 123B: 274, 1937.

[8] F. O. Holmes, *Bot. Gaz.*, 87: 39, 1929.

in .1 M. phosphate buffer at pH 7 (curve A) and in 6.6 M. urea + .1 M. phosphate buffer at pH 7 (curve B) are presented in Fig. 2. The solution yielding data

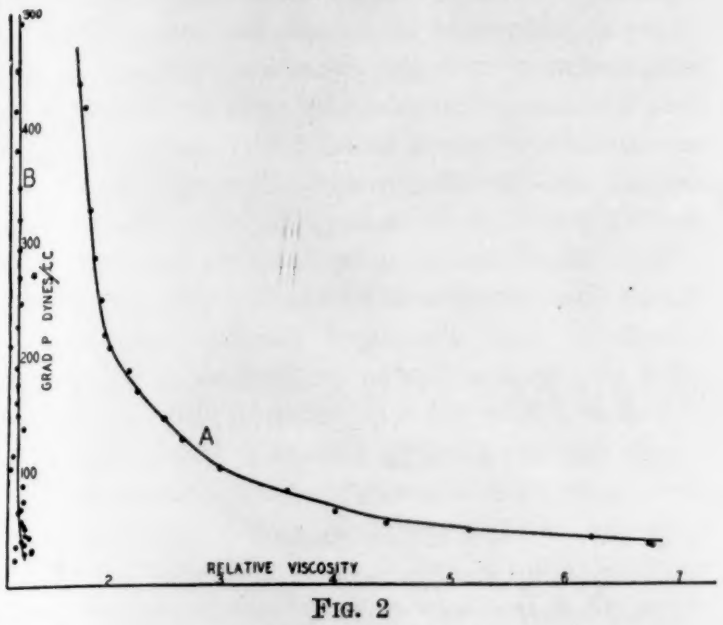

FIG. 2

for curve A contained 4.3 mg protein per cm³, whereas the solution yielding data for curve B contained 6.3 mg protein per cm³. The latter curve was obtained after the virus preparation had stood in the urea for 24 hours. Virus preparations prepared after the method of Stanley[9] show a comparable anomaly when dispersed in either water or in phosphate buffer.

In view of the anomalous viscosity shown by sols of the virus protein in phosphate buffer and the apparent deviation of the diffusion processes from those demanded by Fick's law, it is doubtful that unambiguous values for the particle weight of the chemically prepared virus protein may be obtained by methods involving diffusion in phosphate buffer. A probably less ambiguous value for the particle weight may be obtained from the data for the diffusion in urea solutions. On the basis of the observations presented in this communication, and recalling that a molecule is the smallest particle which can exist as an independent entity, would one not reason that a maximum value for the molecular weight that may be assigned to the virus protein is of the order of 10^5?

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RELATION BETWEEN THE INCREASE IN OPACITY OF YEAST SUSPENSIONS DURING GLUCOSE METABOLISM AND ASSIMILATION[1]

WHEN washed yeast cells are suspended in glucose-phosphate solutions, the opacity of the suspension, as measured by a photoelectric densitometer, increases with time.[2] The rate of change in opacity has been found to vary with the strain of yeast employed, the age of the culture and the experimental conditions. In a typical experiment with Fleischmann's GM strain of bakers' yeast (obtained 2 days after separation at the factory), the optical density (log opacity) changed from 0.170 to 0.417 within 6 hours after the addition of 5 per cent. glucose to cells previously washed and suspended in M/15 KH_2PO_4 (aerobic conditions, 25° C.). The observed change in optical density with time is entirely referable to the suspension and not to the instrument, since variation in the intensity of the light source or in the "constants" characteristic of the phototubes was eliminated by the type of circuit employed and the procedure used in obtaining the measurements.[3] From a consideration of the theory of densitometry as applied to the type of instrument employed,[4] it was apparent that the observed change in optical density resulted from an increase in cell number and from some progressive change in optical characteristics of the cells or from either of these factors operating alone.

We have found no significant increase in cell number under the experimental conditions employed above. This conclusion is based on 11 experiments on GM yeast and 4 experiments on Strain 4360 cultivated in this laboratory. The cell counts were made with a haemacytometer on at least 4 separate samples taken at various intervals during each experiment; 2,000 to 3,000 cells were counted in each sample. In the experiment on GM yeast cited above, the cell counts were as follows: immediately after adding the glucose, 49,640 cells/c.mm.; after 1 hour in glucose, 52,380; after 3 hours, 50,220; after 5 hours, 52,100; and after 6 hours, 52,350. A difference greater than 6 per cent. was considered significant for these suspensions.

Investigations of the changes which the cells of the GM strain undergo with time after suspension in a glucose solution show (a) that the opacity of the individual cells increases with time (evidence from direct microscopic observations and from photomicrographs); (b) that the dry weight per unit number of cells increases progressively with time, very nearly paralleling the increase in optical density of the suspension; (c) that the increase in weight results from the storage within the cells of substances syn-

[9] W. M. Stanley, *Jour. Biol. Chem.*, 115: 673, 1936.

[1] Support from the William F. Milton Fund of Harvard University is gratefully acknowledged.

[2] *Cf.* legend to Fig. 2 in T. J. B. Stier, W. Arnold and J. N. Stannard, *Jour. Gen. Physiol.*, 17: 383–392, 1934, where an increase in opacity under similar experimental conditions was reported.

[3] T. J. B. Stier, W. Arnold and J. N. Stannard, *ibid.*, p. 386.

[4] *Cf.* H. Mestre, *Jour. Bact.*, 30: 335, 1935; and L. G. Longsworth, *Jour. Bact.*, 32: 307–328, 1936.

thesized from the glucose (evidence obtained from chemical analyses of glycogen, total carbohydrate and total fat content); (d) that the cell volume, measured by a centrifuge method, increases with time.[5] The optical density of the suspending medium did not change during 6 hours at 25° C. The evidence obtained indicates, therefore, that the increase in optical density of the suspension is primarily due to progressive changes in optical characteristics of the cells and that these changes accompany the formation and storage of anabolic products within the cells.

On the basis of the above results it is proposed that the changes in optical characteristics of yeast cells during assimilation might be used as indicators of anabolic activity. Thus, the rate of increase in optical density of the cell suspension might be conveniently employed as a measure of the "rate of assimilation." A rapid, optical method for use in exploratory experiments dealing with the dynamic aspects of the assimilation process would obviously reduce the total time and effort demanded by a kinetic type of attack on the mechanism of carbohydrate and fat assimilation. The long, laborious chemical methods of analysis would still be employed, but only for each series of check experiments. Our present densitometer can be employed for this purpose within certain limits. It has been sufficiently reliable for the qualitative detection of whether or not assimilation is taking place in a given yeast suspension in which the total number of cells remains constant with time; it also has given a linear relation between the opacity of the suspension and the per cent. increase in dry weight of the cells during the early stages of carbohydrate assimilation (*i.e.*, during about the first 2 hours at 25° C.). We hope to develop a more satisfactory method of measuring specifically the change in cellular opacity in order to follow with greater accuracy the entire course of carbohydrate and fat storage.

Details of the experiments reported in this paper will be published shortly.

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THE USE OF PURIFIED THROMBIN AS AN HEMOSTATIC AGENT[1]

RECENTLY we have described a thrombin preparation which is far more powerful than any previously reported.[2] In a 1 per cent. solution, 1 cc will clot 1 cc of blood within 2 seconds. Animal studies show that such a solution is highly effective when applied locally to check hemorrhage. It has been found to be non-toxic when used to control the oozing of blood from operative surfaces. For this purpose it is applied by means of an atomizer. Under these circumstances a thin film of blood forms almost instantly, and this seals the finer vessels. The larger vessels are controlled by ligature as a preliminary measure.

With the thrombin spray, profuse bleeding from incised liver tissue can be checked completely in 5 seconds or less. Prolonged bleeding from bone is often very troublesome to the surgeon at the time of operation. With the application of thrombin we are able to stop this bleeding within 5 to 10 seconds. This obviates the need of bone wax, which is a foreign body. With the use of thrombin, we have been able to resect portions of brain and to check with ease the hemorrhage which is otherwise so difficult to control.

The same beneficial effects have been obtained in operations on dogs with a prothrombin deficiency which can be produced by chronic chloroform administration.[3] In such dogs, bleeding is very profuse at operation and may be fatal unless thrombin is applied.

The important applications to human surgery and to human bleeders await further study regarding the sterility of the thrombin preparations.

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ISOLATION OF CRYSTALLINE HETEROTRYPSIN FROM BEEF PANCREAS

NORTHROP and Kunitz have prepared from beef pancreas the two crystalline enzymes, trypsin and chymotrypsin.[1] For both of these enzymes, specific substrates have been synthesized in this laboratory. Trypsin was shown to hydrolyze benzoyl arginine amide, while chymotrypsin was found to split benzoyl tyrosyl glycine amide. Another synthetic substrate, benzoyl glycyl lysine amide, was found to be hydrolyzed by crude pancreatic extracts, but not by trypsin or chymotrypsin.[2] Therefore, the hydrolysis of this lysine compound was attributed to an unknown enzyme

[5] *Cf.* O. W. Richards and T. L. Jahn, *Jour. Bact.*, 26: 385–391, 1933; and L. G. Longsworth, *ibid.*, for discussions of the effect of an increase in cellular opacity and volume during growth by cell division on measurements of population density by the photoelectric method.

[1] Aided by a grant from The John and Mary R. Markle Foundation. Funds for a technical assistant were supplied by the Graduate College, State University of Iowa.

[2] W. H. Seegers, H. P. Smith, E. D. Warner and K. M. Brinkhous, *Jour. Biol. Chem.*, 123: 751, 1938; *ibid.*, 126: 91, 1938.

[3] H. P. Smith, E. D. Warner and K. M. Brinkhous, *Jour. Exp. Med.*, 66: 801, 1937.

[1] M. Kunitz and J. H. Northrop, *Jour. Gen. Physiol.*, 19: 991, 1936.

[2] M. Bergmann and W. F. Ross, *Jour. Am. Chem. Soc.*, 58: 1503, 1936; M. Bergmann, J. S. Fruton and H. Pollok, SCIENCE, 85: 410, 1937.

in the pancreatic extract. This enzyme has been designated heterotrypsin.[3]

It has now been observed that heterotrypsin is contained in exudates from bovine pancreas. With the above-mentioned lysine-containing substrate as a guide, the task of isolating heterotrypsin from the pancreatic exudate was undertaken. This was easily accomplished by a process which consists essentially in a 0.4 saturation with ammonium sulfate at pH 7.0. The enzyme was thus obtained in the form of fibrous crystals which exhibited a very high activity towards benzoyl glycyl lysine amide. The crude crystals contained only traces of trypsin and chymotrypsin. A quantitative study of the action of pancreatic exudates on our synthetic substrates showed that the amount of heterotrypsin in the exudates is several times that of trypsin, while chymotrypsin is almost entirely absent.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

METHOD FOR "FIXING ICE CRYSTAL PATTERNS" IN FROZEN PRODUCTS

IN the course of microscopic studies of fruits and vegetables preserved by freezing, considerable difficulty was experienced in using the paraffin method for obtaining sections. Such tissues as ripe strawberry, peach and raspberry or young stems of asparagus, broccoli and spinach are almost without thickened cell walls; and after they are badly ruptured by ice crystals, become very flabby on thawing. It was found almost impossible to maintain the original structure throughout the long process of paraffin embedding.

Sectioning the thawed material with a sliding microtome was equally unsatisfactory.

After considerable experimenting, a method of sectioning the frozen material was developed which was very rapid and satisfactory.

In this case the microtome and all supplies were placed in a freezing room an hour in advance in order to become thoroughly chilled. Temperatures of the room were varied from 0°F. to above freezing, and it was decided that a temperature below 15° F. was uncomfortably cold and caused sections to be too brittle, while that above 25° F. was objectionable because it permitted partial thawing of the material from the warmth of the body. From 18° to 20° F. was decided to be the most suitable temperature for making frozen microtome sections. A refrigerated truck used for hauling frozen products made an ideal sectioning room.

Tissues of most fruits and vegetables were satisfactorily sectioned from ten to thirty microns thick provided the ice crystals were very small. Those frozen with solid carbon dioxide, by the immersion method or other methods producing a very quick freeze, sectioned as smooth as a block of green soft wood; while those containing large ice crystals could not be cut in sections less than thirty microns thick, and then both cell walls and cell contents were often fragmented. Frozen sections were floated in a chilled, killing and fixing fluid as they were cut and placed in very small petri dishes. Formic-acetic-alcohol (acetic acid 5 per cent., formalin 10 per cent., alcohol 70 per cent., water 15 per cent.) was satisfactory for this as it rendered the sections fairly stiff, which prevented sticking together and made handling much easier. Ice crystal patterns in vegetative tissue were very satisfactorily fixed.

For staining unmounted sections more than a dozen single and double stains were used with some degree of success. Best results were obtained with eosin, orange G and basic fuchsin for staining cell contents, and light green, basic fuchsin and methylene blue for cell walls. Due to lack of secondary thickening in cell walls of most of the material used, double staining was of limited value; however, safranin-Delafields haematoxylin was good for gross anatomical study of asparagus tips, and orange G, light green or safranin-light green was excellent for study of starch grains and cell walls of peas, beans and corn.

This method is very rapid, as the writer has, on numerous occasions, made sections and carried them through the process of dehydrating, staining and mounting in balsam, in one-half day. The adaptability of the method depends not so much on the material, nor on the temperature of the cutting room, as on the initial freezing temperature of the product.

In this way ice crystal patterns could be fixed, measured and photographed very accurately, and thereby establish a means of evaluating methods of freezing fruits and vegetables. The writer has made more than one thousand measurements of ice crystals in about a dozen products frozen by eight different methods.

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A NEW APPARATUS AND METHOD FOR TRAINING THE RAT IN AUDITORY DISCRIMINATION PROBLEMS

SEVERAL investigators have reported from time to time considerable difficulty in training lower mam-

[3] M. Bergmann and J. S. Fruton, *Jour. Biol. Chem.*, 118: 409, 1937.

malian forms, particularly the rat, to respond differentially to auditory stimuli. Still greater difficulty has been encountered in the attempts made to train these animals to localize the direction of sounds and to discriminate pitches and loudnesses. Experimentalists are in general agreement that in problems related either to the peripheral or to the central aspects of the auditory modality one of the major problems is the development of a methodology for training the infra-primate subject. Two major difficulties relative to the available procedures in this field of investigation can be found in the literature. First,[1] certain methods require prolonged training periods and so preclude the formulation of any very detailed operative program. Second,[2] other methods of training eventuate in such decidedly abbreviated responses to auditory stimulation that it is difficult, if not upon occasion impossible in the later stages of learning, to determine whether the animal has or has not responded.

The apparatus and training procedure described at this time, it is believed, overcomes to a certain degree these difficulties. The apparatus consists of a modified living cage, the floor of which is an electric grid. Located within this cage and resting on the grid is a small platform which may become if need be a second grid. Acclimatization of the animal, in our experiments the rat, is permitted by placing it in the cage some hours before beginning the preliminary training. During this initial training period the animal is given a series of twenty shocks per day and is required to jump upon or down from the secondary grid-platform. Following the acquisition of this shock-escape response, a buzzer or a thousand-cycle tone is presented and is followed by the shock. All animals so far tested learn rapidly within the range of individual differences to escape the shock by making the appropriate shock-avoidance response. Thus in this experimental arrangement only one response can be made, namely, movement away from the present position. The rapid learning of the rat which has thus far been observed permits in terms of the time element the initiation of a more detailed operative program involving a study of cerebral mechanisms in audition.

The modified cage arrangement described above permits numerous modifications. It is believed this apparatus could be enlarged and consequently utilized for larger mammals, such as the cat, the dog and the guinea pig. Certain evidence already available shows the possibility as well as the plausibility of training animals to discriminate between tones on the basis of pitch and loudness differentia. A further modification for the study of auditory localizing behavior is in progress. Obviously, however, the size of the cage floor, the size of the second grid and the construction of the walls of the cage will depend upon the nature of the study as well as upon the size of the animal subject. In this particular arrangement the walls have been constructed of galvanized iron. A screened top with mirror arrangements obviates certain recording difficulties. The use of the solid walls thus makes impossible an alternative wall-clinging response. From one point of view, however, it is suggested that this response itself might be found sufficient for the determination of a statistically reliable response to sound stimuli.

The values of this modified living cage method in training the rat to respond to sound stimuli are numerous. First, the method is sufficiently simple to make unnecessary the cradle arrangements use by Britt[3] and Schlosberg.[4] Second, the experimental arrangement is comparatively close to the normal living conditions of the animal. The artificiality of the Y-maze arrangement[5] in relation to sound stimuli is somewhat obviated. Third, as a corollary of the above, the rapidity with which modifications in behavior occur makes possible the study of certain little understood brain mechanisms in at least one sense modality. Fourth, the response of the animal under the conditions of these arrangements is always clear-cut and observable. Fifth, the use of shock as an incentive seems from several points of view to be superior as a motivating agent over food. Shock can be controlled and measured in more rigorous fashion. Sixth, the possibility of the study of certain other sense modes in relation to cerebral function is suggested by the method of training just outlined.

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[3] S. H. Britt, *Jour. Comp. Psychol.*, 19: 243, 1935.
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